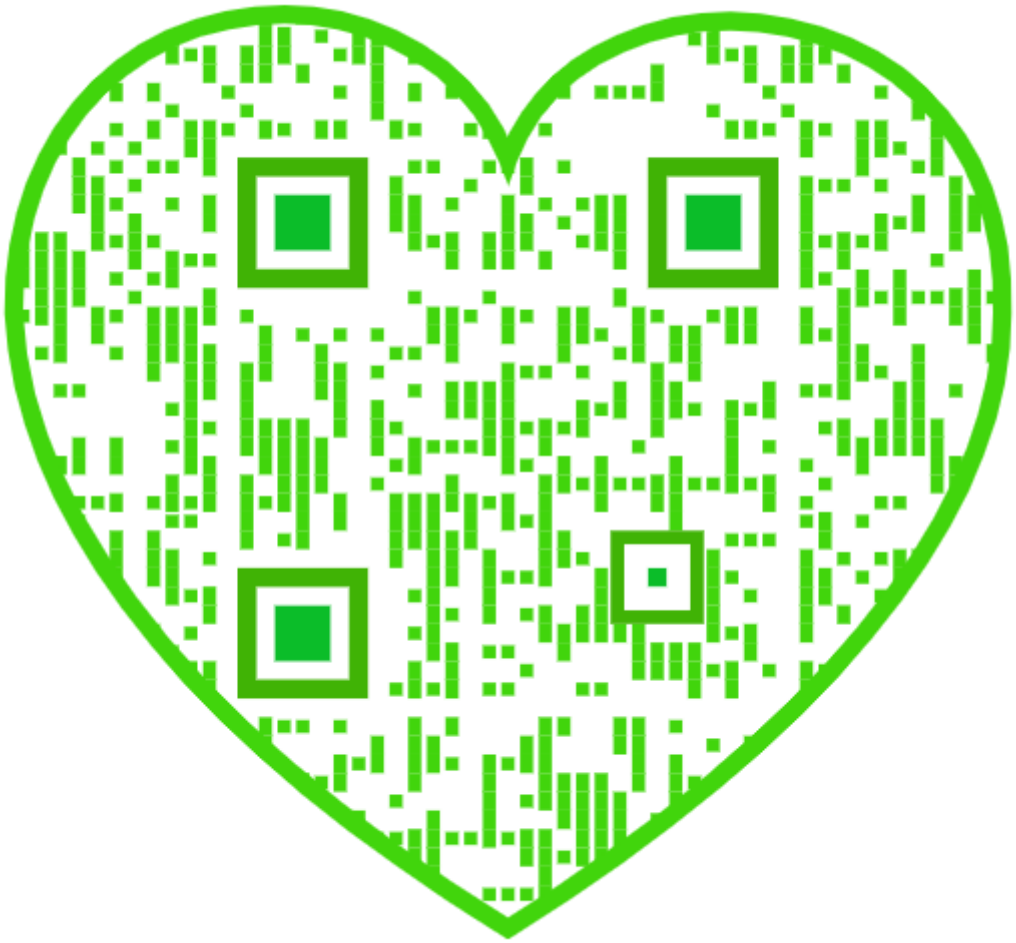
DOMESTIC SCIENCE

BY

DR. J. E. TALMAGE.



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DOMESTIC SCIENCE.

A BOOK FOR USE IN SCHOOLS AND FOR GENERAL READING.

(SECOND AND REVISED EDITION.)

— BY —

JAMES E. TALMAGE,

(D. S. D., PH. D., F. R. M. S.)

"Till, by experience taught the mind shall learn
That, not to know at large of things remote
From use, obscure and subtle, but to know
That which before us lies in daily life,
Is the prime wisdom."—*Milton.*

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DEDICATORY.

TO

KARL G. MAESER, D. L. D.,

To whom the author owes so much, this unpretentious volume is respectfully and affectionately inscribed.

FROM PREFACE TO FIRST EDITION.

The author has endeavored to bring together, in a simple manner, such topics as have a direct bearing upon the science of domestic operations. His object has been to direct attention to daily household affairs,—affairs indeed, which to many are too common to be deemed worthy of earnest thought. The kitchen and the pantry may be made a laboratory for the elucidation of many important facts of science; and as interest is aroused in the necessary labors of the household, much of the unwelcome air of drudgery will vanish from such work. As it is plain that the duration of our mortal existence permits the exploration of but a small fraction of the domain of knowledge, careful judgment should be exercised in the selection of subjects of study; the practical and utilitarian aspect of modern systems of education testifies to the wide recognition this fact has received among the people in general.

In this book, no effort has been made to secure an unduly elaborate or an exhaustive treatment; a large work would be poorly adapted for class use, and much detail might discourage the general reader in his study. Liberal reference has been made to the works of recognized authorities on the subjects treated; in such cases, acknowledgment has been made in the body of the work. A few passages are reprints of articles that have appeared over the author's signature in local periodicals.

PREFACE TO SECOND EDITION.

"DOMESTIC SCIENCE" having been adopted by the Territorial Convention of School Officers, as a text book for the District Schools of Utah, the publication of a second edition is rendered necessary. The author has endeavored to improve the little work by correcting a few typographical and other errors of the first issue, and by adding a brief set of review propositions at the end of each chapter. These with the addition of a few statements, a re-arrangement of some paragraphs, and some omissions, constitute the principal changes, the main plan of the work remaining unaltered. The publishers have had prepared a new series of illustrative cuts, which will doubtless be appreciated.

For the measurement and calculations relative to the Tabernacle in Salt Lake City, the author is indebted in this, as in the first edition, to Architect Don C. Young.

It is hoped that the book in its present form will prove of some value to the writer's fellow-laborers,—teachers and students.

J. E. T.

SALT LAKE CITY, UTAH,
DEC., 1892.

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DOMESTIC SCIENCE.

PART I.

AIR AND VENTILATION, WITH CHAPTERS ON HEATING AND LIGHTING.

CHAPTER I.

SOME PHYSICAL PROPERTIES OF AIR.

Existence of the Atmosphere.—It is generally believed that the earth's surface is covered to a depth of several miles by a gaseous substance known as *air* or *atmosphere*. Owing to its transparency, this covering is not apparent to our powers of sight; there are however, other means by which we may become convinced of its existence. When the air is in motion, it gives rise to the phenomenon of winds; and the speed with which the moving air travels determines the difference between the pleasant zephyr, and the destructive hurricane. The following simple operation will conclusively prove the existence of the atmosphere:

Fig 1.
Air preventing entrance of water.

Place a cork on water contained in a large bowl or other convenient vessel; take now a tumbler or a goblet, and while holding it vertically, with the open end downward, lower it over the floating cork, pressing downward until the glass is submerged. As the cork does not rise within the glass, we know that the water has not entered.

Now, a very simple, yet proper question is, what keeps the water from filling the inverted goblet? Liquids, it is correctly said, show a tendency to seek their levels. There must be something inside the glass, which presses against the water, and prevents its entrance. Had it not been for the pressure exerted by this invisible something, the water would have risen to the same height within the vessel as without, or until the glass was entirely filled. This may be made much clearer by another experiment:—

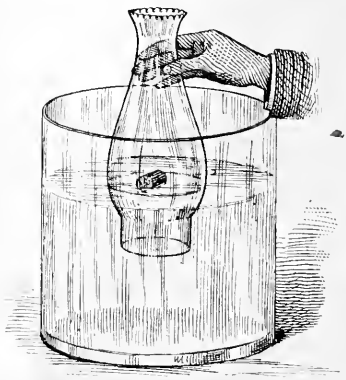


Fig 2.
Water expelling air.

Take an ordinary lamp chimney, which of course, is open at both ends. While holding it in a vertical position, push the chimney into the water as was done with the tumbler in the former experiment. The liquid will stand at the same level inside and outside the chimney. The water, in this case, pushes the air from the open glass, and takes its place. If the chimney had been previously filled with smoke from a bit of burning rag, or thick, coarse paper, the movements of the escaping air, as it overflowed the chimney, would be clearly visible.

Impenetrability of Air.—The following very beautiful illustration of the impenetrability of air is suitable for the lecture table, and can be performed by anybody who will provide himself with a few simple requisites

in the way of apparatus, and who will exercise a moderate degree of patience and perseverance. In the figure, A represents a wide-mouth bottle, capable of holding a pint or more; this is provided with a tightly fitting cork, through which two holes are bored. B is a funnel-tube passing through one of the perforations in the cork; a piece of wide glass tubing could be employed, though less conveniently, instead of the funnel tube. C represents a delivery

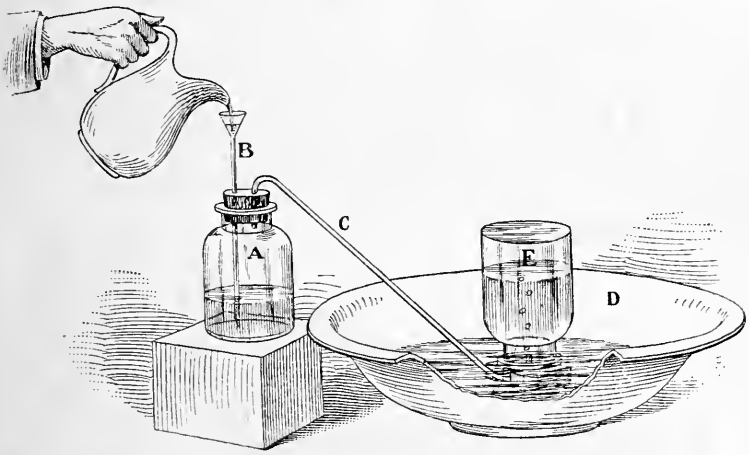


Fig. 3.
Impenetrability of Air.

tube of glass; this may be easily shaped from a piece of glass tubing of the required length, first softened in a lamp flame. D is a basin or any suitable vessel containing water, beneath the surface of which the delivery tube C terminates. E is an ordinary bottle, which is to be first filled with water, then inverted over the end of the delivery tube, and there supported

on any convenient stand, or held in position by the experimenter.

Now, as water is poured through the funnel tube into the bottle, air is forced therefrom, and escapes through the delivery tube into the inverted vessel. It may be shown by measurement, that just as much air is crowded out as water is poured in. Thus we see that this transparent, invisible air possesses in its own degree many of the properties of other heavier matter. It occupies a definite amount of room, and prevents other things occupying that space at the same time.

Weight of Air.—The atmosphere also possesses weight. By carefully weighing a closed vessel filled with air, and then weighing it again after the air has been drawn out by means of a pump, the weight of air has been accurately determined. By such means it has been found that a cubic inch of dry air at the surface of the sea weighs .31 grains. A hundred cubic inches would weigh therefore 31 grains; and a cubic foot would weigh 535.68 grains, or about 1.11 ounces. About 14.4 cubic feet of dry air would be required to weigh a pound. A sitting room of ordinary size, say 14 feet long, 12 feet wide and 9 feet high, would contain nearly 105 pounds of air; and a large room suitable for public assemblies, say 40 feet by 40 feet, and 18 feet high, would hold about a ton of air.

Effect of Altitude on Weight of Air.—These calculations apply only to air at the sea level; at greater altitudes the atmosphere is less dense, so that fewer

particles are contained in a given space. At the altitude of Salt Lake City, a cubic inch of dry air weighs only .26 grains; a cubic foot weighs .93 ounces; and 17.2 cubic feet weigh one pound.

Elasticity of Air.—An interesting demonstration of the elasticity of the atmosphere may be made with the apparatus shown in figure 4. A hollow body, which is best made of glass or porcelain, and which, as in the figure, may be shaped like a balloon, is immersed in water within a tall glass cylinder. The balloon is partly filled with water, the remaining space being, of course, occupied by air. A very small hole near the lower end of the balloon permits water to pass in or out. A piece of sheet rubber is tied over the mouth of the jar. Any pressure applied on the rubber is transmitted by the water to the air confined in the balloon; this air becomes compressed, and consequently more water enters the balloon, which therefore sinks. When the pressure on the rubber top is removed, the elasticity of the air in the balloon expels the excess of water; and the balloon rises.

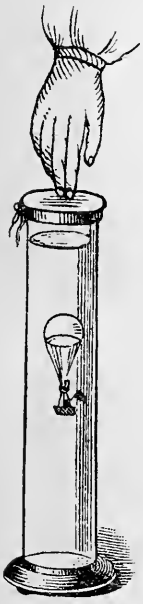


Fig. 4. Showing elasticity of air.

Pressure of Liquids.—It is well known that liquids exert a definite pressure on bodies immersed in them. A forcible demonstration, which may readily be performed by ocean voyagers, is as follows: A stout bottle is tightly corked, and then attached to a long cord,

weighted, and thrown overboard, the string being paid out as fast as the bottle sinks. After a considerable depth has been reached, the cord is drawn in. In most cases, the cork will be found forced into the bottle through the great pressure of the water. If, however, the cork used was of the "Tom Thumb" pattern, so that it could not enter, the bottle may be crushed.

Atmospheric Pressure.—In an analogous way, the air presses upon every object on which it rests. To demonstrate: Completely fill a drinking glass with water; lay over the top a piece of glazed note paper; hold the latter firmly in position by placing the palm of the hand over it, and invert the vessel. The pressure of the air will hold the paper in position against the mouth of the glass after the hand has been removed, and in spite of the weight of the water which rests upon the paper. This is illustrated in figure 5.

Fig 5.
Upward pressure of the air.

This demonstration may be very prettily varied by first tying a piece of coarse muslin over the top of the glass. The vessel is to be filled with water, covered with a piece of paper, and inverted as before. If the paper be then carefully drawn away, the water is still

kept within by the upward atmospheric pressure, which is exerted on the water within the vessel; while the bottom of the rigid glass receives the downward pressure, but does not communicate it to the liquid within. The upward pressure therefore operates without the downward pressure to counter-balance it.

Another experiment should follow: Instead of a glass vessel use a common fruit can, the cover having been

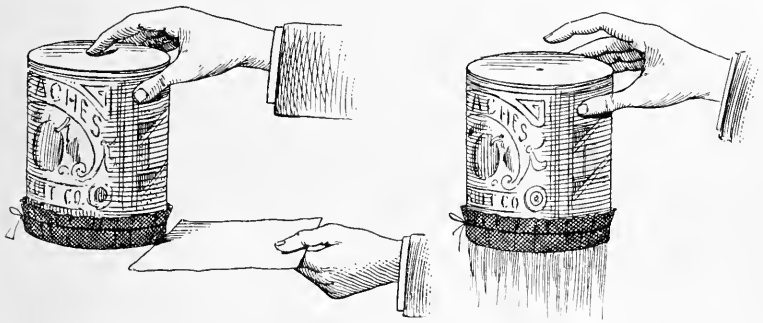


Fig. 6.
Atmospheric pressure.

removed, a piece of muslin tied over as before, and a small hole punched in the opposite end, as shown in the illustration, figure 6. Now place the finger over the small opening; fill the vessel with water, cover with a piece of glazed paper, and invert as before. When satisfied that the pressure of the air sustains the water within the can, remove the finger, and immediately the liquid flows out, the downward atmospheric pressure being communicated to the contents of the vessel through the tiny aperture. This

downward pressure with the weight of the water added, is evidently greater than the upward pressure of the atmosphere alone. The latter is overcome, and therefore the liquid falls.

Expansion of Air by Heat.—An interesting demonstration may be made by taking a hard-boiled egg, from which the shell has been carefully removed. A bottle, with a mouth sufficiently large to partially but not completely admit the egg, is to be provided. Place now in the bottle a bit of burning paper; or hold within it by means of tongs a "live" coal. The effect of the heat is to expand the air, causing much of it to pass entirely out of the bottle. Now put the egg in position, like a stopper within the mouth. As the air within the bottle cools, it contracts; the outer air, in its endeavor to enter the bottle, presses on the egg, and forces it inward, frequently with a loud report.

The expansion of air by heat may be further illustrated in this way: Take a small cup, burn a bit of paper within it, or hold a glowing coal by tongs as in the case of the egg and bottle experiment, described above. The air becomes heated and expanded, and a portion is driven out. Now remove the fire, and press the mouth of the cup on the fleshy part of the arm. As contraction by cooling occurs, the experimenter is made aware of a strong, and even painful tendency of the flesh to enter the vessel. This is a crude illustration of the surgical operation of *cupping*, which was in general use years ago. By

such means, blood and other matter could be drawn from an affected part of the body without the use of the lancet.

The Air Pump.—Many other demonstrations, no less instructive than impressive, may be made by the aid of an *Air Pump*. The essential points in the

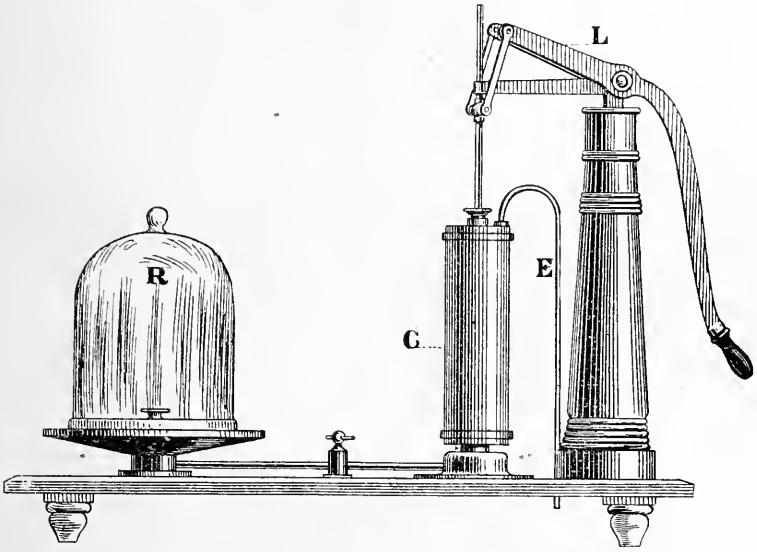
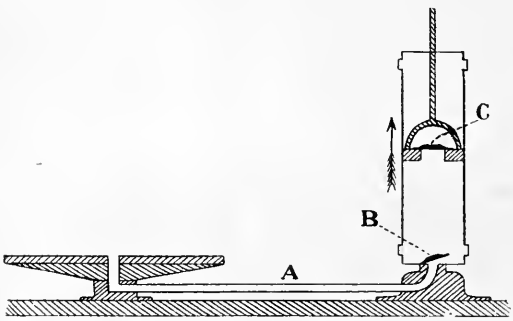


Fig. 7.
Air Pump.

construction of this useful instrument will be understood by reference to the cuts. Figure 7 shows the complete instrument. C is the cylinder, within which a piston works, operated by the lever L. As the piston is raised, air is drawn from the large globe or receiver R on the left. The mode of operation will be seen by a study of figure 8, which shows the air pump

in section. A valve, C, is connected with the piston, within the cylinder; a second valve, B, is situated at the bottom of the cylinder; these valves open only in an upward direction; a tube, A, leads from the receiver-plate to the cylinder. As the tightly-fitting piston is raised, air passes through the tube A, opens the valve B, and fills the space between the piston and the bottom of the cylinder. With the first down-stroke, the air confined within the cylinder becomes compressed, it forces open the piston valve, and escapes. In subsequent strokes more air is drawn through the tube A, and a globe or receiver placed upon the plate over the entrance to A would soon become exhausted. In figure 7, E represents an exit tube, which conducts the air from the upper part of the cylinder.



Fig, 8.
Section of Air Pump.

Hand-glass Experiments.—As an impressive illustration of atmospheric pressure, place a hand glass, which is simply a hollow cylinder open at both ends, over the aperture in the air pump plate; now cover the upper opening with the hand. As the air is exhausted, the hand is firmly held against the vessel. A piece of sheet rubber may be tied over the

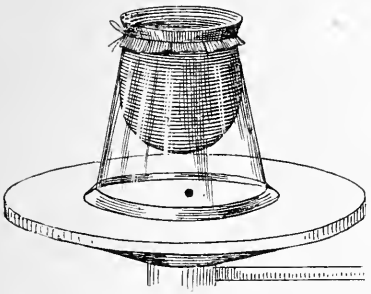


Fig. 9.
Sheet rubber under pressure.

open glass; as shown in figure 9; as the air is drawn out the rubber is forced into the jar so as almost entirely to cover the inside. If instead of the rubber, a piece of bladder be tied over the jar, the air pressure from above will burst the bladder inward with a loud report.

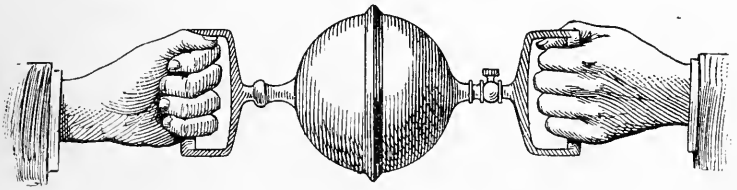


Fig. 10.
Magdeburg hemispheres.

The Magdeburg Hemispheres furnish a still more striking effect of atmospheric pressure. These are two hollow half globes, made to accurately fit each other at the edges. The air is exhausted from within by attaching the pair to the air pump; after which the stop-cock is turned to prevent a re-entrance of air. The pressure of the atmosphere is so strong, that very great force is required to pull the hemispheres apart. (See figure 10.) The apparatus derives its specific name from the fact that the first experiment of the kind is supposed to have been made at Magdeburg, by Otto von Guericke, in 1654. It is said that he used hemispheres so large and effective, that after the air had been

exhausted, twenty horses were unable to pull them apart.

Air Supporting a Column of Liquid.—Take a bottle, fill it completely with water, place over the opening a plate of glass, invert it with its mouth just below the surface of water in a larger vessel, as in figure 11. The water remains in the bottle, though it stands far above the level in the outer vessel; it is held there by the downward pressure of the air which is received on the surface of the liquid in the outer

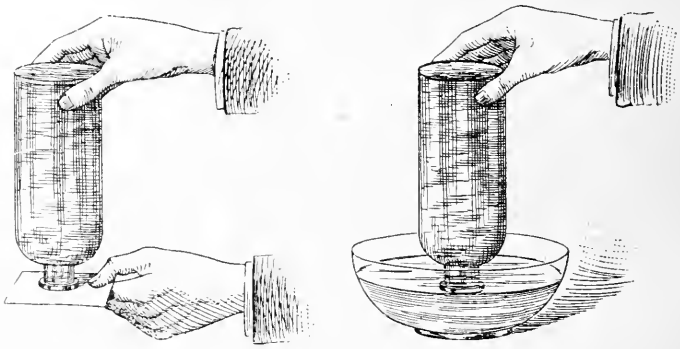


Fig 11.
Air pressure supporting a column of water.

vessel, and thence transmitted to the contents of the bottle. It is very readily seen, that as the mouth of the inverted bottle is below the surface of the water in the larger vessel, air could not enter the bottle from without, even if the contained water could be withdrawn. This phenomenon was discussed as long ago as the days of Aristotle, the noted Grecian philosopher, who has been dead now about twenty-one centuries.

He taught the people, that "*Nature dislikes a vacuum.*" By "vacuum" is meant an empty space, one that is devoid even of air.

REVIEW.

1. Describe an experiment to prove the existence of the atmosphere.
2. Describe experiments to prove that air is impenetrable.
3. How may the weight of the atmosphere be demonstrated?
4. Give illustrations of the weights of measured quantities of air.
5. Compare the weights of equal volumes of air at the sea level and at the altitude of Salt Lake City.
6. Explain the difference.
7. How would you prove that air exerts pressure?
8. Demonstrate the expansion of air by heat.
9. Explain the surgical operation of "cupping."
10. Sketch the principal parts of the air pump, and explain the operation of the instrument.
11. Describe and explain the hand glass experiment.
12. Explain the operation of the Magdeburg hemispheres.
13. Describe a demonstration of air pressure supporting a column of water.
14. How did Aristotle attempt to explain this phenomenon?

CHAPTER 2.

SIMPLE INSTRUMENTS UTILIZING ATMOSPHERIC PRESSURE.

Atmospheric Pressure Measured.—We may very properly ask if there be a limit to the supporting power of the air; or if the atmospheric pressure which sustains the water in the bottle, as described in the preceding chapter, would be able to hold a column of liquid of indefinite height. This question has been answered by experiment. If at the sea level we could take a tube, say thirty-six feet long, and closed at one end, fill it with water, and invert it with its open end beneath the surface of water, the liquid would sink to the level of thirty-four feet, leaving a vacuum in the upper part of the tube for the space of two feet. This fact caused Galileo, who lived in the earlier part of the seventeenth century, to gravely assert: "Nature does not dislike a vacuum beyond

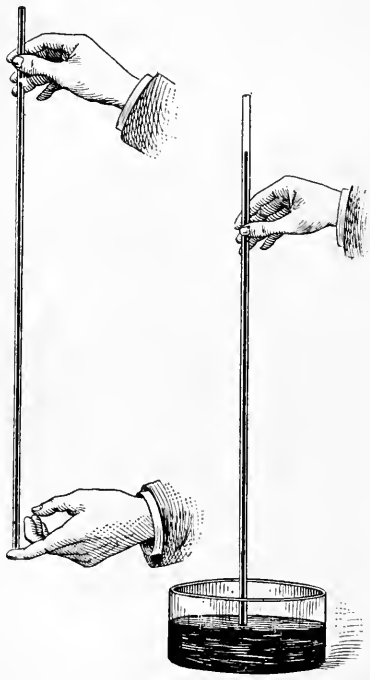


Fig. 12.
Air pressure supporting column of mercury.

thirty-four feet." The true explanation evidently is that the air pressure is just powerful enough to support a column of water thirty-four feet high. If a tube be filled with mercury (quicksilver), and inverted in a vessel of the same liquid, the column will be sustained at the level of thirty inches. If the tube be longer than thirty inches, the mercury will fall to that level, and a vacuum will be formed in the upper part, as illustrated in figure 12. Now mercury is 13.6 times heavier than water; and 34 feet, which is the height at which the water column may be sustained, is 13.6 times 30 inches, which latter is the height at which the mercury column stands. In other words, a column of mercury 30 inches high, would weigh the same as a column of water of equal diameter 34 feet high. Here then is a very convenient method of measuring the pressure of the atmosphere. Suppose the tube used in the experiment with quicksilver described above, has a cross-section of 1 square inch; the mercury stands 30 inches high, therefore the tube contains 30 cubic inches of the liquid; and this amount of mercury is found by trial to weigh about 15 pounds. We may conclude, therefore, that the *pressure of the air is equal to 15 pounds per square inch.*

Effect of Altitude on Air Pressure.—This last statement, however, is strictly true only under the conditions prevailing at the sea level; for the atmospheric pressure is found to vary greatly at different altitudes. The higher we proceed above the level of the sea, the less becomes the air pressure. By carefully noting at different stations the height at which the mercury

stands in a tube arranged as described above, the relative altitudes of those places may be determined with fair accuracy. At a height of four miles above the sea level, the mercurial column would be about half its ordinary height, or fifteen inches; and at an elevation of twenty miles it is supposed the pressure would not support a column higher than one inch. At the altitude of Salt Lake City, the mean height of the mercurial column is 25.6 inches; this corresponds to a pressure of 12.8 pounds per square inch. At this altitude, the body of a man of medium size, possessing 2000 square inches of surface, would sustain a weight of 25,600 pounds, or 12.8 tons; at the sea level such a person would be under a pressure of 30,000 pounds, or fully 15 tons. However, as there is air within the body, this enormous pressure is equally balanced.

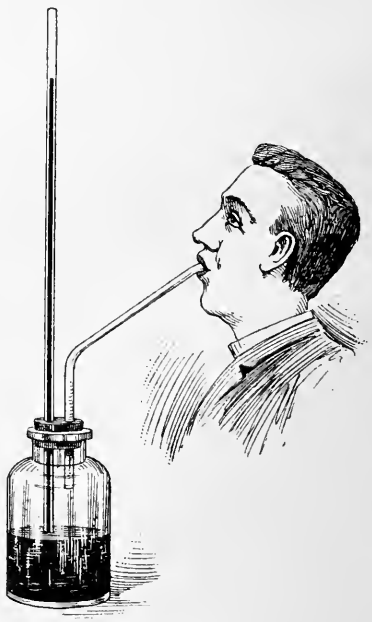


Fig. 13.
Showing fluctuations of the mercurial column.

The roof of the large Tabernacle at Salt Lake City measures 42,500 square feet; the air pressure thereon amounts to 39,168 tons; at the sea level, with the mercurial column at 30 inches, such a surface would be under an atmospheric pressure of 45,900 tons.

The Barometer.—Such an instrument as that already described,—a tube of proper length filled with mercury and inverted in a cistern of the same liquid, is usually called a *Barometer*, the term meaning "weight measurer." Many different forms of barometers are now in use; the most accurate being the mercurial barometer similar in principle to the kind already described. To demonstrate the effect of varying air pressure on the barometric column, proceed as follows, (see figure 13): Invert a barometer tube filled with mercury in a bottle of the same liquid. Provide a doubly perforated cork, which tightly fits the bottle mouth; insert the cork with the inverted tube passing through, and place a short tube in the other perforation. By blowing through the short tube, an increased pressure is exerted on the mercury within the bottle, and the column rises. By applying suction, some of the air is drawn from the bottle, the pressure upon the contained mercury is lessened, and the column falls. Thus we may see illustrated within a room such barometric differences as exist between the mountain-top and the sea-level.

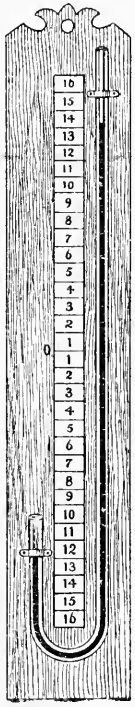


Fig. 14. Siphon barometer.

Siphon Barometer.—A very good instrument is the siphon barometer, illustrated in figure 14. This consists of a glass tube

of proper length, bent upward at the bottom so as to form two arms of unequal length. The short arm is open, the long arm closed. When the tube is filled

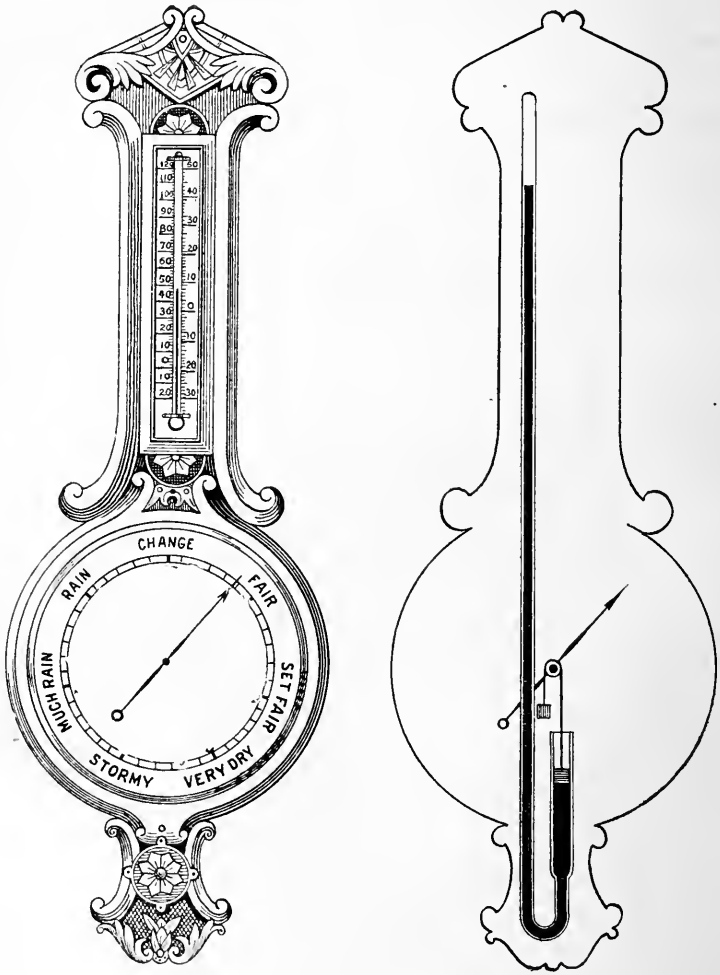


Fig. 15.
Wheel barometer.

with mercury and inverted, a vacuum is formed in the upper part of the long arm, the height of the liquid column depending upon the prevailing atmospheric pressure. The tube is permanently graduated above and below a point, selected near the middle of the long arm and marked zero (0). The height of the column is determined by reading the level of the mercury in the long arm above 0, and that in short arm below 0, and adding the two readings.

An interesting variation in the siphon form of barometer is the *Wheel Barometer*, the operation of which will be understood from figure 15. Resting on the mercury in the short arm of the tube is a float, which rises and falls with the liquid. By means of a string and pulley, these movements are communicated to an axis upon which a needle is fixed. This needle moves in front of a graduated disc on which the different states of the weather, such as "change," "fair," "stormy," "rain," etc., are marked.

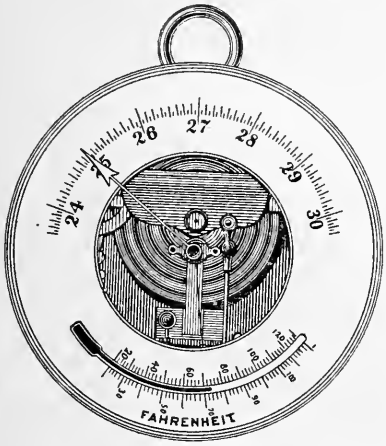


Fig. 16.
Aneroid barometer.

Aneroid Barometer.—Another very convenient instrument is the so-called aneroid barometer, (figure 16), in general shape not unlike a watch. The air

pressure is transmitted from a very thin and flexible metallic casing to a system of levers acting upon the dial finger. The dial is graduated to correspond with a standard mercurial barometer.*

The Barometer and the Weather.—Even at a fixed station the barometric reading is seldom constant for any great length of time, from which fact we learn that the atmospheric pressure is continually varying. Sudden and violent weather changes are usually accompanied by fluctuations in the barometric column. But the common belief that a decreasing pressure, as indicated by a fall in the barometric height, is an infallible indication of approaching storms, and that a "rising barometer" is surely indicative of fair weather, can scarcely be relied upon. We have not yet mastered the true science of weather indications. The wind still "bloweth where it listeth," irrespective of our artificial rules. Our confidence in the barometer's indications should not be impaired on this account. That little instrument simply informs us of changes in atmospheric pressure; if we interpret such information to mean rain, wind, or fair weather, we do so of our own accord: the barometer told us no such thing.

The so-called Storm Glass.—There is an instru-

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*The word *aneroid* means literally, "without moisture," and is applied to this form of barometer because no quicksilver or other liquid is used in its construction. A good aneroid is a sensitive instrument, even capable of showing the difference in atmospheric pressure between a table top and the floor beneath.

ment known as the storm glass, now in common use. It consists of a sealed tube containing a chemical solution, in which crystals appear with varying profusion. It is plain that the pressure of the air can in no way affect the contents of the tube, as the latter is hermetically sealed. The author has made systematic observations on a number of the instruments, and finds then entirely unreliable as indicators of atmospheric pressure. The solvent power of the contained liquid is affected by changes in temperature, and the instrument has a stronger semblance to claim as a thermometer than as a barometer. The "storm glass" is well designed as a selling article and as a wall ornament.

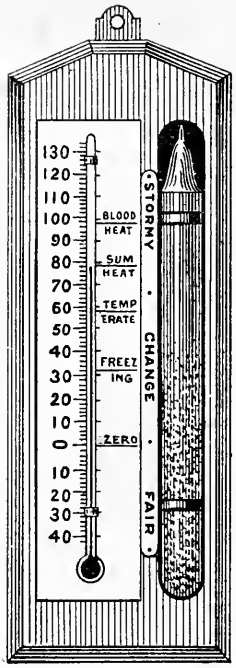

Fig. 17.
Storm glass.

Syringe and Pump.—The pressure of the atmosphere is turned to practical account in the construction and operation of many simple instruments, among which the pump is prominent. An essential feature of the pump is illustrated by the common syringe. In figure 18 a vessel of water is shown; in it are inserted two cylinders, each provided with a tightly-fitting piston and a convenient handle. In the figure on the left, the piston is at the

bottom of the cylinder; in the right hand sketch the piston is partly raised, the water following it.

The Lifting Pump, (figure 19) consists essentially of a barrel containing a piston and valves, oper-

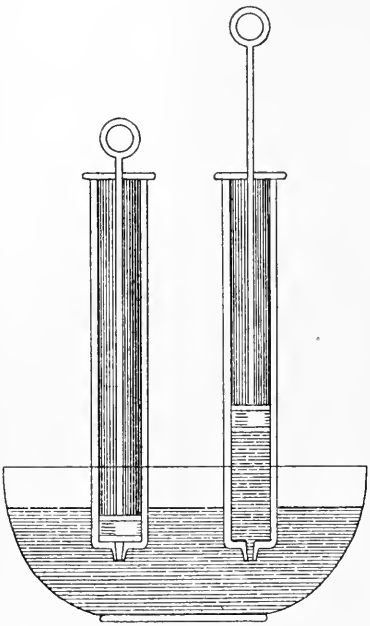

Fig. 18.
Syringe.

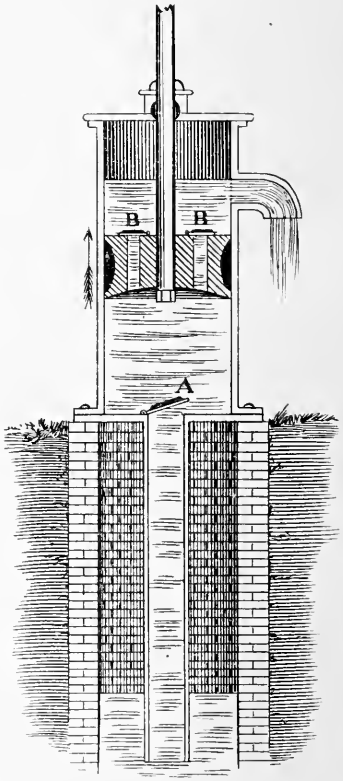

Fig. 19.
Lifting pump.

ated by means of a lever handle. A pipe passes from the pump barrel to the well. At A is placed a valve, so constructed as to open only upward. Any pressure received from above tightly closes the valve.

Other valves similar in action are placed in the piston at B. As the piston ascends, the water follows it, owing to the pressure being relieved within the barrel, while the atmosphere presses with ordinary intensity on the water surface in the well. The force of the inflowing water is sufficient to force open the valve A. As soon as the down stroke of the piston begins, however, the pressure closes the barrel valve, while the water forces up the piston valves, and fills the space above the piston. This water is lifted to the spout at the next upstroke.

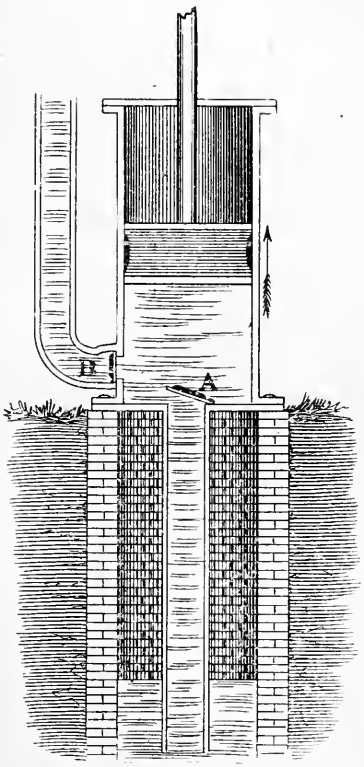

Fig. 20.
Force pump.

Limits of Efficiency in Lifting Pumps.—As before explained, the atmospheric pressure at the sea level is about 15 pounds to each square inch, and this is sufficient to raise and sustain a column of water 34 feet high. Under the most favorable circumstances therefore, if the full pressure of 15 pounds to the square inch were realized, water could not be drawn by a lifting pump from a greater depth than 34 feet; and in actual

practice, through imperfect action of the pump, this theoretical efficiency is never attained. Lifting pumps are seldom able to draw water more than 28 feet. This is equal to a little more than 12 pounds to the square inch. At this altitude (Salt Lake City) under exceptionally favorable circumstances, lifting pumps

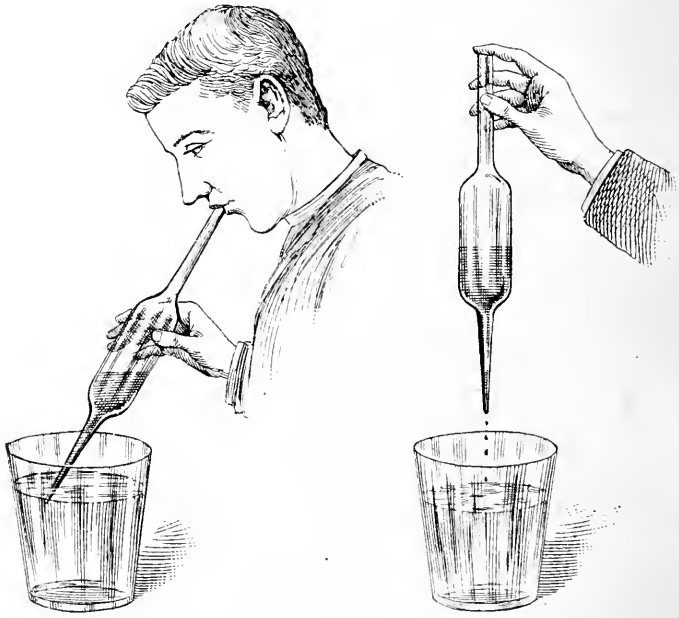

Fig. 21.
The Dropping Tube or Pipette.

may draw water from a depth of 22 feet; but as a rule, 18 feet is considered a maximum, and 16 feet is the general limit of efficiency.

Force Pump.—If it be desired to lift water to a greater height than this, a force pump must be employed. This device (figure 20) is provided with a solid piston and a pair of valves; one valve

A being set in the barrel, as in the case of the lifting pump, and the other, B being connected with a discharge pipe, through which the water is driven by the down stroke of the piston. The limitations to the operation of the force pump lie in the strength of the material from which the pump is constructed, and in the power applied.

The Dropping Tube, or Pipette, is based on the application of air pressure (see figure 21). By applying suction at one end, while the other end is immersed in liquid, the tube may be filled; the finger then being so placed as to close the upper opening, the liquid can be held in the tube and be allowed to escape as desired. Such tubes may easily be made from ordinary glass tubing (figure 22.) Pipettes will be found of great service in many simple operations of the household, such as the measuring of flavoring extracts, medicines, and the like.

Fig. 22.
Simple Pipette.

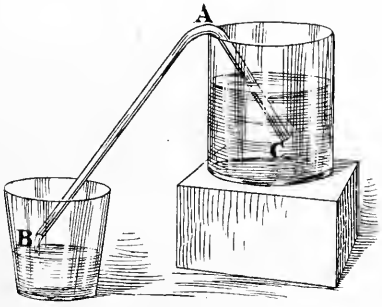

Fig 23.
The Siphon.

The Siphon (figure 23) consists essentially of a bent tube, with arms of unequal length. If the short arm, C A, be inserted in any liquid, and suction be applied

at the end of the long arm, A B, the liquid may be drawn through the tube. and will continue to flow after the suction has ceased.* This simply device may

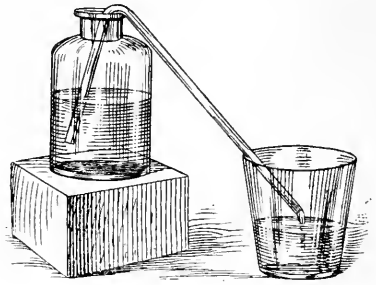

Fig. 24.
Siphon transferring liquid without disturbing sediment.

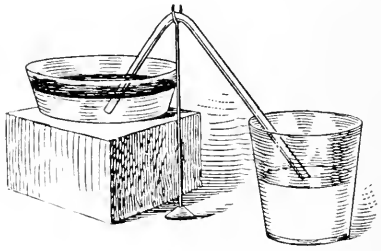

Fig. 25.
Siphon transferring liquid without disturbing top layer.

*If the siphon be filled with liquid, the ends closed, and the short arm inserted in a vessel of liquid, a flow will take place without suction being applied. The explanation of the siphon in operation is simple. When the tube is filled with liquid the upward atmospheric pressure is equal at the ends B and C, (fig. 23.) But this upward pressure is diminished in the long arm by the weight of the liquid column A B, and in the short arm by the weight of the column A C. Evidently there will be a lower upward pressure at B than at C; hence the flow is started from C toward B; and if the end C be placed beneath the surface of a liquid, the flow will continue as long as C is immersed, or until the liquid stands at the same level in the two vessels.

be made of much practical service in the kitchen and the cook-room. Liquids may be drawn off in a clear condition without disturbing bottom sediment (figure 24), or top scum (figure 25). Milk may be taken from the setting pans without disturbing the cream, by inserting the tube beneath the cream layer.

REVIEW.

1. At what height will the atmospheric pressure at the sea level sustain a column of water?
2. At what height may a column of mercury be supported by atmospheric pressure at the sea level?
3. Explain fully how the atmospheric pressure per square inch may be determined.
4. At what height may a mercurial column be supported by air pressure at the altitude of Salt Lake City?
5. Give illustrations of the atmospheric pressure on the body of a man at the altitude of Salt Lake City and at the sea level.
6. Sketch apparatus and explain a demonstration of varying air pressure on a column of mercury.
7. What is a barometer?
8. Name the principal kinds of barometers with which you are acquainted.
9. Describe and explain the siphon barometer.
10. Describe and explain the wheel barometer.
11. Explain the operation of the aneroid barometer.
12. What do you know of the barometer as a foreteller of weather changes?
13. What do you know of the so-called storm glass?
14. Explain the operation of the common syringe.
15. What is a pump?
16. With what classes of water pumps are you acquainted?
17. Sketch and explain the lifting pump.
18. The force pump.
19. State the theoretical and the practical working distance of lifting pumps at Salt Lake City, and at the sea level.
20. Sketch, describe, and explain the pipette.
21. Explain the action of the siphon.

CHAPTER 3.

COMPOSITION OF THE ATMOSPHERE.

Constituents of the Atmosphere.—Until comparatively recent times, the atmosphere was supposed to be elementary in its composition, that is, composed of but one simple substance. Now, however, it is known to be made up of several components, the most plentiful ingredients being *Nitrogen*, *Oxygen*, *Carbon Dioxide*, and *Watery Vapor*. The first two, namely, nitrogen and oxygen, are present in much the largest proportions, there being about four-fifths or 80 per cent. nitrogen and one-fifth or 20 per cent. oxygen. The carbon dioxide and the watery vapor are present in very small and variable quantities. In its condition of ordinary purity, the air contains about one cubic inch of carbon dioxide per cubic foot.

It has been calculated that if the atmosphere could be compressed to a total depth of five miles, the vapor of water being condensed to the liquid form, and the atmospheric constituents being arranged in separate strata, the relative amounts would be shown as follows: The water would form a sheet over the earth about five inches deep, above this would be a layer of carbon dioxide thirteen feet in depth, then a stratum of oxygen nearly one mile deep, and lastly, one of

nitrogen four miles in thickness. Such an illustration is intended for comparison only; the constituents of the air are not so separated; on the contrary, there is a most intimate mixture of all, the heavy and the light ingredients being mingled at the surface in practically the same way as at the greatest heights.

Diffusion of Gases.—This perfect mixing is brought about by the operation of that wonderful law of nature, called by man the "Law of the diffusion of gases." To illustrate, we may perform the following experiment: Let us take two large bottles placed mouth to mouth, (as in figure 26), the upper one containing a very light gas, dry hydrogen for instance, and the lower one a comparatively heavy gas, ordinary air will answer. In a very short time, part of the heavy gas will have risen into the upper bottle, and a portion of the light gas will have sunk into the vessel below, and the two will be uniformly mixed. We can easily determine that the air and the hydrogen have become mixed, by separating the bottles and applying a flame to the mouth of each; an explosion occurs. Neither pure hydrogen nor air is explosive of itself, but a mixture of air and hydrogen explodes with vigor when a flame is applied. Now, air is about 14½ times heavier than hydrogen; yet the tendency toward diffusion is so strong that the heavy air rises and the

Fig. 26.
Diffusion of gases.

light hydrogen sinks till a perfect intermixture is effected.

Uniformity of Atmospheric Composition.— By such a process of diffusion, the composition of our atmosphere is rendered practically uniform throughout. Air has been analyzed from mines and deep valleys, as well as from mountain tops; from above the sea as well as from the land surface, and from the upper deeps of the atmospheric ocean as reached by balloon ascents; yet the only differences thus far discovered are such as are due to accidental contamination; the proportions of the essential ingredients being practically constant in all cases.

We should learn something regarding the individual characteristics of each of the principal ingredients of the atmosphere.

Nitrogen; its Preparation.— Nitrogen is the substance present in greatest quantity. This is a colorless gas, without appreciable taste or odor. It may be prepared in a comparatively pure state by removing the oxygen of the air, and this can be done through combustion. Provide any convenient stand, as shown in illustration, (figure 27). This must be set in a bowl of water, so as to project several inches above the water surface.

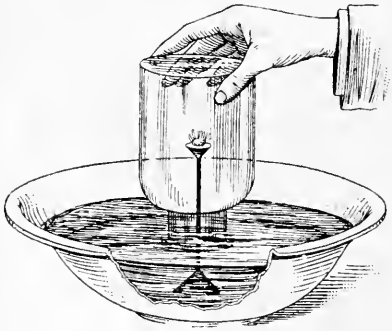

Fig. 27.
Preparation of nitrogen.

Place on the top of the stand a bit of *phosphorus** about the size of a No. 3 shot. Light the phosphorus by touching it with a heated wire, and then quickly invert over it a large wide-mouth bottle, which is, of course, filled with air. Lower the bottle over the burning phosphorus so as to keep the mouth of the vessel sealed by the water. Dense white clouds appear in the bottle; these consist in reality of a fine white powder, formed by the union of the burning phosphorus with the oxygen of the air within the jar. After a short time, this powder dissolves in the water, and the bottle is found to contain about one-fifth of its full capacity of water, which has risen from below; the remaining four-fifths are occupied by a colorless gas; proper tests will prove this to be nitrogen.

Relative Amounts of Oxygen and Nitrogen in the Air.—The fact that the bottle becomes about one-fifth full of water is significant. As the burning phosphorus removed the oxygen of the inclosed air by uniting with it to form phosphoric acid, which was dissolved in the water, evidently the space formerly occupied by the oxygen would be left unfilled, unless the water passed in. As one-fifth of the space originally occupied by the air is found filled with water,

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* Phosphorus should be used only by those who have some knowledge of its properties. It is intensely poisonous and very readily inflammable. In fact, it must be kept always under water, and even while being handled it must be covered with water to prevent its taking fire. The fumes of burning phosphorus are very injurious, and phosphorus burns in the flesh are deep and painful.

it is clear that one-fifth of the original substance has been removed; and this amount must have been the oxygen. The remaining gas, four-fifths in amount, is nitrogen. When the contents of the bottle have become entirely clear, we may place a plate of glass under the mouth of the vessel, remove from the bowl, and invert.

Some Properties of Nitrogen.—If now a burning taper or a flaming splinter be introduced into the bottle, the flame will be immediately extinguished, thus proving the inability of nitrogen to support combustion. A further experiment has been performed, but we need not repeat it; it is cruel, though it embodies a lesson. If a small animal, a mouse, for instance, be placed in a bottle of nitrogen, the little creature quickly dies with all evidences of suffocation. Nitrogen, then, is a passive, inert gas, incapable of supporting combustion or of sustaining life. Its chief value as an ingredient of the atmosphere seems to be that of a dilutent for the more vigorous oxygen associated with it.

Preparation of Oxygen.—Oxygen, the second ingredient of the atmosphere in point of abundance, is not so easily prepared in a state of purity. The removal of the nitrogen of the air, so as to leave the oxygen in a pure state, is almost an impossibility. But other methods of obtaining the gas may be employed:—Make an intimate mixture of *potassium chlorate* and *manganese dioxide*; place the same in a flask A, provided with a delivery tube C, and a

collecting bottle B, connected with a pneumatic trough,* as shown in figure 28.

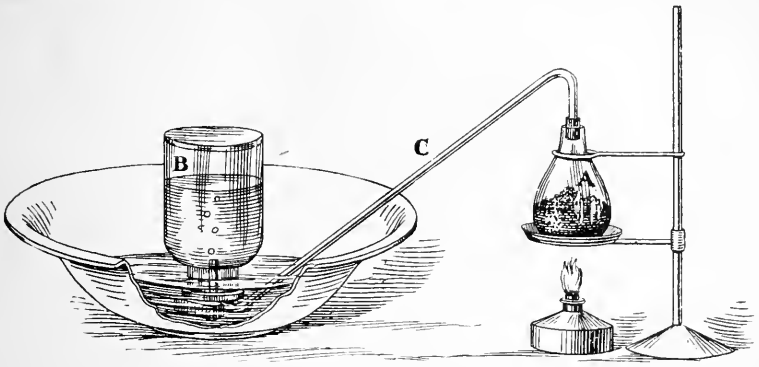

Fig. 28.
Preparing Oxygen.

Now apply heat to the flask. Soon a gas is delivered through the tube with considerable rapidity; this gas is oxygen.

Some Properties of Oxygen.—If a lighted taper or splinter be introduced into the oxygen, the flame is greatly increased in brilliancy. A bit of phosphorus, when lighted and introduced into oxygen, burns with blinding brightness. A piece of steel wire may be made to burn in this gas as easily as a shaving of wood. In demonstrating the combustion of metallic wire, a bit of wood is to be first fastened to the wire and lighted; the wire then takes fire from the wood. An animal placed in pure oxygen gives signs of feverish exhilara-

* A vessel to be used in collecting gases as is the bowl in figure 3 and in figure 27, is called a *pneumatic trough*. It may consist of any convenient vessel for holding water, having a shelf or blocks for the support of the receiving vessel, which is to be inverted over the end of the delivery pipe.

tion, and if compelled to breathe the gas for any great length of time the creature dies of excessive excitement.

Oxygen and Nitrogen Compared.—A greater chemical contrast could scarcely be found than that which exists between inert nitrogen and active oxygen. If the oxygen were taken from the air, men and animals would speedily die of suffocation; if the air consisted of pure oxygen the tissues of our bodies would soon be worn out, and death would result from the unnatural energy of the vital processes. In an atmosphere of undiluted oxygen, a combustion once started would soon become universal; the metal of our fire-places would burn with the fuel, and nothing would escape the general conflagration but that which had already been burned. The fact that combustion is possible in the air, points to the presence of oxygen; the additional fact that such combustion is far less energetic than in pure oxygen, suggests the presence of a diluting ingredient, such as nitrogen.

Carbon Dioxide—Mode of Preparation.—Carbon dioxide is itself a compound substance, consisting of the elements carbon and oxygen. It may be prepared for study by pouring a strong acid on marble, or on sodium carbonate, and catching the escaping gas. A bottle is to be provided with a doubly perforated cork, carrying a funnel tube and a delivery pipe arranged as in figure 29. In the bottle a tablespoonful of marble dust, or better still, the same quantity of baking soda, is to be placed. A little dilute muriatic acid is to be poured through the funnel tube upon the marble dust

or soda. A gas is given off with vigor, and may be collected as was the oxygen, over the pneumatic trough.

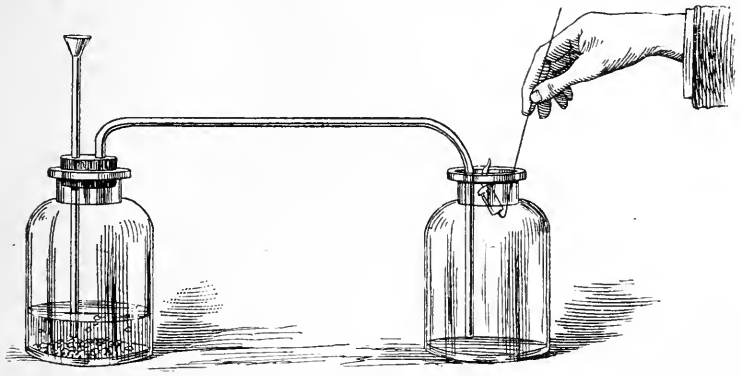

Fig. 29.
Preparation of carbon dioxide.

Some Properties of Carbon Dioxide—If a lighted taper be introduced into a vessel containing carbon dioxide, the flame is extinguished as speedily as if plunged into water. A living animal placed in the gas dies very speedily after a few ineffectual gasps for relief. This carbon dioxide is considerably heavier than air. The gas may be poured from one vessel to another, as shown in figure 30. It may be dipped by a small vessel from a larger one as

Fig. 30.
Pouring carbon dioxide.

readily as water. Owing to its great weight, the gas may be collected, as illustrated in figure 29, by displacement instead of over water. The delivery tube in such a case is to be passed to the bottom of the collecting bottle. A lighted candle held at the mouth will be extinguished as soon as the vessel is filled. If we continue to pass the gas into a vessel after the latter has become full, the gas will run over as water would do under similar circumstances. True, the substance is transparent and colorless, and therefore entirely invisible, but a candle flame held alongside the receiving vessel will reveal the overflow (see figure 31).

Fig. 31.
Carbon dioxide overflowing.

Carbon Dioxide from Fermentation. — The writer once visited a large vinegar factory in the State of Maryland. The vats in which the mash was placed to ferment were each as large as a sitting room. These vats were only half filled with mash, the upper space being left for the gathering of the carbon dioxide which is given off in the process of fermentation. On the occasion of the visit referred to, a double quantity of mash had by mistake been pumped into one of the large vessels. There was, of course, no room for the carbon dioxide to collect, and it ran over the sides of the vat as fast as produced. Several workmen who were engaged in repairing the

floor around this particular vat were quickly enveloped in the suffocating gas, and died before assistance could be rendered.

Tests for Carbon Dioxide.—Its power of extinguishing a flame is a usual method for determining the presence of carbon dioxide; but it will be remembered that nitrogen possesses the same property. A more reliable test may be made as follows:—Prepare a little clear lime water, by adding water to good lime and afterward filtering. Pour a little of this into a bottle containing carbon dioxide; then shake. The lime water becomes at once milky from the formation of insoluble lime carbonate, resulting from a union of the lime and the carbon dioxide. By exposing a dish of lime water to the atmosphere, with occasional shaking, after a time a turbid appearance is produced, indicating the presence of carbon dioxide, which must have existed in the air.

Watery Vapor in the Air.—The existence of vapor of water in the atmosphere is a fact scarcely to be wondered at. If a vessel of water be exposed freely to the air, after a short time the liquid is found to have disappeared. The particles of water have not been destroyed. They have, in fact, been lifted into the air by the process of evaporation, and there they float as freely as the other constituents of the atmosphere. A very simple proceeding will prove the presence of watery vapor in the air about us.

Provide a glass of ice water for observation. See that the outside of the vessel is perfectly dry. Set the glass in a warm room, and observe. In a short time

the outside of the glass becomes covered with drops of liquid looking not unlike dew. This moisture must have come from the atmosphere of the room. Under all circumstances water can be condensed from the atmosphere if the temperature be sufficiently lowered.

Capacity of Air for Moisture ; Saturation.—The quantity of moisture which the air can absorb and hold in suspension depends largely upon the temperature. Warm air has a much greater capacity for moisture than has cold air; and the process of cooling the air results in the deposition of much of the water which it held. When the air contains all the moisture it is capable of holding at any given temperature, it is said to be saturated. At the freezing point of temperature, (32° F.) the air is saturated with moisture when it contains 2.3 grains of water to the cubic foot. At 60° F. a cubic foot of air will hold 5.8 grains of moisture; at 90° F. it will hold 14.3 grains; and at 100° F. it may contain 19.1 grains. In the cold season, therefore, the air may appear moist because it is near its saturation point, though in reality it contains at such time much less moisture than under conditions of greater warmth. Evidently the *drying power* of the atmosphere will depend upon its capacity to take up more moisture than it already holds. It is customary to express the drying power of the atmosphere in degrees, the determination being made by finding the difference between the temperature of the air and the dew point.

Air Overcharged with Moisture.—When under any circumstances the air becomes charged with

moisture beyond its point of saturation, some form of precipitation is the result. The deposit may occur in the form of dew, or, if larger quantities of water are condensed at the time, as by a sudden cooling of a heavily laden cloud, the fall may be one of rain, snow, or hail, as the temperature may determine.

Summary.—Let it be remembered then that the air contains four essential, constant ingredients:—*nitrogen*, *oxygen*,, *carbon dioxide*, and *vapor of water;* and beside these, several other accidental constituents, such as gaseous emanations from decaying matter, the volatile materials of fuel, the aroma of flowers, and the like. The nitrogen and the oxygen form the bulk of the atmosphere. These are present in the proportions here shown:—

	BY WEIGHT.	BY VOLUME.
Oxygen	23.1 per cent.	20.9 per cent.
Nitrogen	76.9 " "	79.1 " "
	100.	100.

The average quantity of water present in the atmosphere is perhaps nearly 1 per cent, and that of carbon dioxide is about $^1/_{2000}$ of the air by weight.

REVIEW.

1. What is a chemical element?
2. Name the substances present in the atmosphere.
3. State the relative amounts of these ingredients present in the atmosphere.
4. Explain the law of the diffusion of gases.

5. Show the operation of this law upon the atmosphere.

6. How would you separate nitrogen from the other atmospheric ingredients?

7. Describe the principal physical properties of nitrogen.

8. Describe the chief chemical properties of nitrogen.

9. How would you prepare oxygen for experimental purposes? Sketch the apparatus you would employ.

10. Describe a series of demonstrations of the power of oxygen in supporting combustion.

11. Compare oxygen and nitrogen as to their chemical properties.

12. What is a chemical compound?

13. How would you prepare carbon dioxide for experimental purposes?

14. How would you demonstrate that carbon dioxide is heavier than air?

15. Describe the principal chemical properties of carbon dioxide.

16. Describe a chemical test for the presence of carbon dioxide.

17. Demonstrate the existence of watery vapor in the atmosphere.

18. Show the effect of varying temperature on the capacity of the atmosphere to hold moisture.

19. What is meant by the air being saturated with moisture?

20. Explain dew point.

21. Explain the drying power of the atmosphere.

CHAPTER 4.

PERMANENCY OF THE ATMOSPHERE.

Conditions of Change in Atmospheric Constituents.—The uniform and constant composition of the atmosphere appears all the more remarkable, when we consider the many influences of change to which most of the ingredients are subject. As has been already seen, the nitrogen of the air is an inert constituent; though mixed with other substances, it takes no part in the transformations which they so readily undergo. Air is taken into the lungs of men and animals, and though the oxygen is there exchanged for carbon dioxide, the nitrogen passes out again in an unchanged state. In all fires, oxygen combines with the fuel, and thus adds to the energy of the blaze, but the nitrogen remains still passive and free. The oxygen and the carbon dioxide, however, are continually undergoing change by an endless series of rapid combinations and decompositions. Let us, then, turn our attention to these.

Effect of Respiration on Air Composition.—In breathing, men and animals inhale by drawing a portion of air into the lungs; and after an interval, they exhale or expel about the same quantity of gaseous matter, though of a composition far different from that taken in. Expired air contains more carbon

dioxide, and a far lower proportion of free oxygen than does air before respiration. Blow through a small tube, a straw will answer well, into a vessel of clear lime water: the milky appearance (see chapter 3,—carbon dioxide) indicates the presence of carbon dioxide in the breath. This is true of the breath of animals as well as of human beings. When we strive to think of the number of living beings constantly breathing, and thus removing oxygen from the air and supplying carbon dioxide thereto, the causes of the permanency of the atmosphere become still more perplexing.

Oxygen Supplied to the Air.—It would seem to us at first thought, that after a time all the oxygen of the air would be consumed, and in its place would be a superabundance of the deadly carbon dioxide. Beside the respiration of animal bodies, there are many other causes by which atmospheric oxygen is consumed and carbon dioxide produced; such as the combustions in lights and fires, the decay of organic matter, and all common processes of fermentation. In some portions of the earth, vast volumes of carbon dioxide are thrown into the air from volcanic fissures and rents, from carbonated mineral springs, and the like. It is calculated that over 300,000,000 tons of coal are annually

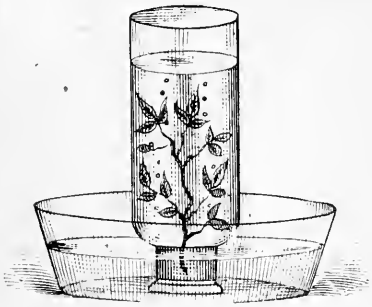

Fig. 32.
Leaves exhaling oxygen.

burned in the world under present conditions. This alone would produce upward of 800,000,000 tons of carbon dioxide gas. A century ago but an insignificant fraction of this amount was consumed; yet the composition of the atmosphere seems not to have been altered by this immense supply. There must be some powerful influences in operation, through which oxygen is restored to the air and carbon dioxide abstracted therefrom. An experiment on this subject was made in 1774 by Dr. Priestly, an English chemist, and it has been repeatedly verified since that time. Each of us may make the demonstration his own by proceeding as follows (see figure 32): Place a sprig of green leaves, freshly plucked, in a bell jar or large bottle, and fill the vessel so as to cover the leaves with water that has been charged with carbon dioxide. Then invert the bottle in a larger vessel of water, place the whole in direct sunlight, and watch results. Very soon, bubbles of gas are seen rising from the leafy surfaces; and these bubbles, being lighter than the water, collect at the top of the bottle, the heavier liquid sinking to give them space. When a sufficient quantity of gas has been collected, place a piece of glass beneath the mouth of the bottle, and set the vessel right side up. Now introduce a lighted candle or splinter into the gas; the increased brilliancy of the flame declares the substance to be oxygen. The carbon dioxide with which the water was originally charged has disappeared in the process. It is therefore clear to us, that, under the influence of sun-

light the leaves have absorbed the carbon dioxide, and have exhaled oxygen in its place.

Carbon Dioxide Removed from Air by Plants.—If compelled to re-breathe their own exhalations, animals would soon die for want of oxygen; yet the foulest emanations of animals' lungs, the suffocating carbon dioxide, forms the chief support of the plant. Under the influence of sunlight, the green leaves of plants, through their multitudes of tiny pores, draw in the carbon dioxide from the atmosphere, and exhale the life-giving oxygen. Says Professor Johnson, "On a single square inch of the leaf of the common lilac as many as 120,000 breathing pores have been counted; and the rapidity with which they act is so great that a current of air passing over the leaves of an actively growing plant is almost immediately deprived of the carbonic acid it contains." And again, "A common lilac tree, with a million of leaves, has about four hundred thousand millions of pores or mouths at work, sucking in carbonic acid; and on a single oak-tree as many as seven millions of leaves have been counted."

Chlorophyle-bearing Plants; Fungi.—This power of the leaves is exerted only under the influence of sunlight, direct or diffused. The active principle of the leaf, by which the decomposition of carbon dioxide is effected, is technically known as *chlorophyle*, a word meaning "leaf-green," and so used because the substance is usually of a green color, and by its presence imparts the prevailing hue to foliage. The word scarcely expresses the whole nature

of this potent compound, for in the case of multi-colored leaves, as for example, the petals of flowers, the varied tints are apparently imparted by a substance identical in most respects other than color with the chlorophyle of green leaves. Plants that contain no chlorophyle, (fungi), such as the mushroom, toad-stool, and the like, exhibit none of the colors of the higher plants, and they flourish when entirely deprived of light. Such plants do not decompose the carbon dioxide of the atmosphere, but they exhale this gas, and consume oxygen as do animals.

House Plants.—Chlorophyle-bearing plants, when deprived of light act somewhat similarly to the fungi, thus rather vitiating than purifying the air. In the open air, the carbon dioxide evolved during the hours of darkness by growing plants has but slight effect upon the purity of the atmosphere; but in closed spaces, as the rooms of houses, the result is different; and therefore it is considered injurious to sleep in rooms containing growing house-plants. Though during the bright hours, these beautiful growths are alike pleasing in their effects upon the mind and body, in darkness they tend, however slightly, to increase the contamination which is so constant a feature of animal and human existence.

Agency of Plants in Drying the Soil.—In marshy districts, growing plants exert another influence of great benefit, since by the absorption of water through their roots they aid in drying the soil. The sun-flower and the eucalyptus tree have been used

in experiments of the kind with very satisfactory results.

Carbon Stored in the Earth.—If we have read at all aright concerning the past history of our earth, there was a time at which the decomposition of carbon dioxide through the agency of plant life took place on a scale vastly greater than that of the present. In that period of the earth's growth which is known as the Carboniferous Age, one of the preparatory stages through which the earth passed before it was fitted for animal life, the air was strongly charged with carbon dioxide. At that time, however, vegetation flourished on the earth with a luxuriance far beyond any comprehension based on present circumstances. In that age there existed extensive forests of mammoth ferns, gigantic club-mosses, and huge trees of many strange growths. All lived by decomposing the carbon dioxide of the air, fixing its carbon, and returning its oxygen in the gaseous state. That carbon has ever since been buried deep in the stony fastnesses of the globe, there undergoing change until converted into coal.* Of the importance of coal, but little need be said. Without it, the world could not be what it is today. Now, by burning the coal, its carbon unites once more with oxygen to form carbon dioxide, and thus the air receives again the substances taken from it through the subtle agency of plant life ages ago.

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* Read chapter 43, "A Talk about Coal," in the author's "First Book of Nature."

Carbon Dioxide Removed by Certain Animals.—But lest the carbon dioxide should become too plentiful for animal welfare, the Creator has wisely directed other influences to operate in again removing this ingredient of the atmosphere as fast as it is produced. Go walk upon the sea beach, and there watch the mollusks, great and small—shell fish as we usually term them—living in such profusion; observe them carefully, and see what they are about. The stone-like shell forming the creature's home, consists principally of calcium carbonate: and of this substance two-fifths, or forty per cent., is carbon dioxide. Then let us sail into warmer climes, and there observe the myriads of coral polyps so successfully fighting the battle of life with the angry breakers of their ocean home. The substance that we ordinarily call coral is indeed nothing but the shell in which the tiny creatures lived; and this shell is composed mainly of calcium carbonate taken from the waters, and containing the proportion of carbon dioxide already named. The beautiful marbles which man ever has delighted to polish and admire, and the massive limestone pillars, buttresses of the mighty hills—are made also of calcium carbonate, holding its proportion of carbon dioxide imprisoned by the powerful bonds of chemical force.*

Mutual Dependence of Animals and Plants.—Upon such a plan does the Creator maintain the equable balance of the elements. Is it not wonderful

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*Read chapter 40, "About Limestones," in the "First Book of Nature."

that the animal, in the unconscious exercise of its own vital processes, contributes to the support of the humble plant? And the plant is not unmindful of the aid thus received. The field of growing corn, while preparing aliment for the support of a higher life, the rose bush perfecting its flowers with which to please the eye, adorn the home, and inspire the heart of man, the vine laboring to ripen its tempting clusters, each, all are purifying the atmosphere, and preserving the equilibrium without which animal life would soon cease to exist on earth. What, then, is independent in nature? The mighty oak, and the gay squirrel which finds food and shelter beneath the hospitable branches of the tree, are mutually dependent. Neither the animal nor the plant can say to the other, "I have no need of thee." Each has been prepared by its Creator to be a support to the other. Could any power possessing aught less than infinite wisdom have planned and executed so perfect, so admirable a design?

REVIEW.

1. What do you know of the changes through which the atmospheric constituents are constantly passing?
2. Show the effect of animal respiration on the composition of air.
3. How is the supply of atmospheric oxygen maintained?
4. How is the carbon dioxide prevented from becoming excessive in the atmosphere?
5. Describe a demonstration of the effect of growing plants yielding oxygen to the air.

6. What do you know of the number of breathing pores on leaves?

7. Define "chlorophyle."

8. State a use of chlorophyle in plants.

9. Define and illustrate "fungi."

10. What is your opinion of the good or ill effects of keeping growing plants in living rooms?

11. State what you know of the Carboniferous Age.

12. Show the effect of corals and mollusks in removing carbon dioxide from the atmosphere.

13. What do you know of marbles and limestones as holders of carbon dioxide?

14. Show the mutual dependence of animal and plant life.

CHAPTER 5.

THE AIR OF ROOMS.

Air of Closed Rooms. — The contaminating influences to which the atmosphere is subject through human and animal respiration, have been already referred to. The atmosphere of closed rooms shows the effects of such influences to a much greater extent than does the open air, for the chief reason that enclosed air possesses far less opportunity of purifying itself. Combustion of lights and fires within the room, and the respiration of the inmates, work together in consuming oxygen and producing carbon dioxide.

Contamination of Air by Human Beings.— But this is not the only change. Large quantities of water, in the form of vapor, are being continually thrown into the air, from the lungs and the skin of living beings. That this is true of the lungs may be demonstrated by breathing upon any cold polished surface. To prove that the same statement applies to the skin, the following simple experiment may be made: Take a large dry bottle, with the mouth sufficiently wide to admit your hand. See that the hand is clean and dry, and introduce it into the bottle; then wrap a cloth around the wrist to seal the mouth. After a short time, the inside of the bottle becomes dimmed with moisture, which increases till it gathers in drops

and trickles down the sides of the vessel. The skin over the whole body is pierced with innumerable tiny openings, through which vapor is continually escaping, unless these pores have become closed through uncleanliness or disease. As a result of numerous experiments, it is believed that the quantity of fluid matter escaping in one day from the skin of an adult person, is not less than from two to three pounds.*

Foul Matter from Exhalation. — But this liquid excretion from the skin and the lungs is not pure water; it is indeed strongly charged with the products of animal decay. By way of proof as to the impure nature of the liquid matters in the breath, proceed in this way: Take a clean dry bottle, having a wide neck: hold it before your mouth, and breathe into it for some time. Then close it tightly, and set it in a warm place for an hour or so; after this, remove the stopper, and apply the nose with critical care. A fœtid odor will be experienced; most probably of a convincing strength.†

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*Dr. Faraday, of well merited fame, said upon this subject: —"I think an individual may find a decided difference in his feelings when making part of a large company, from what he does when one of a small number of persons, and yet the thermometer may give the same indication. When I am one of a large number of persons, I feel an oppressive sensation of closeness, notwithstanding the temperature may be about 60 degrees or 65 degrees, which I do not feel in a small company at the same temperature, and which I cannot refer altogether to the absorption of oxygen, or the inhalation of carbonic acid, and probably depends upon the effluvia from the many present."

† Such putrescible matter is constantly formed in the air of inhabited rooms; it settles upon the walls and furniture and its thorough removal, if indeed at all possible, is a difficult under-

A few years ago, an experimenter caused a number of persons to breathe through tubes into a closed vessel surrounded with ice, by which means the vapor of the breath was condensed in considerable quantity. Some of this liquid was injected into the blood vessels of dogs and other animals. The process was followed in almost every case by speedy death of the victims with all appearances of poisoning.

Service Rendered by the Sense of Smell.—Though the organs of smell are of wondrous delicacy in enabling us to detect the presence of foul or offensive matters, the sense may be easily dulled, so that we become oblivious to the most disgusting odors. Note the sickening effect which one experiences on re-entering a close bedroom, after having been in the open air for a time, though perhaps the person may have occupied that room during the entire night in complete unconsciousness of its foul condition. It is proper that every person should seek to preserve the delicacy of each of his senses. No power of sensation has been implanted within the human organism without a definite use and purpose for the benefit of the possessor. It is probable that we do not comprehend the full purpose of the power of smell; yet it is easy to perceive how we are warned against inhaling many poisonous emanations, through their disagreeable

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taking. Upon these offensive substances those natural and necessary scavengers, the greatly abused house-flies, largely feed, and but for these useful little creatures we would be in a still worse plight.

odors. Though there are some gaseous poisons which are utterly devoid of odor, nearly all fœtid and disgusting smells indicate the presence of poisonous matters.*

Danger from Unclean Surroundings. — Many serious disorders have been directly traced to the breathing of the foul gases arising from decaying matters. The close proximity of stables, cow-houses, pig-pens, and the like, is a constant menace to the inmates of any house so situated. However, contamination of the air from such causes may surely be detected by a keen sense of smell.†

Foul Emanations in Wet Localities. — In wet localities, quantities of the injurious *carburetted hydrogen* (marsh gas) originate from the rotting matters in the soil, and though this gas is itself with-

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* The delicacy of the sense of smell in detecting inconceivably small particles of matter diffused through the air, is illustrated by the oft-quoted statement of Dr. Carpenter:—"A grain of musk has been kept freely exposed to the air of a room, of which the doors and windows were constantly open, for a period of ten years, during all which time, the air though constantly changed, was completely impregnated with the odor of musk, and yet, at the end of that time, the particle was found not to have sensibly diminished in weight."

† "The offensive trades mentioned in the Public Health Act of 1875" (England) "are those of blood-boiler, bone-boiler, fellmonger, soap-boiler, tallow melter, tripe-boiler. The model byelaws of the local Government Board include in addition, those of blood-dryer, leather-dresser, tanner, fat melter or fat-extractor, glue-maker, size-maker, and gut scraper, as being trades for which regulation by sanitary authority is desirable."—*Parkes.* These occupations are all attended by foul odors, and such pursuits the sanitary authorities of England have found it advisable to restrict.

out odor, yet when arising from such source it is always associated with ill smelling gases.

In such localities, too, and more especially in volcanic regions, and in the vicinity of "sulphur springs," the air is rich in *sulphuretted hydrogen*, sometimes called from one of its very un-inviting sources, "rotten-egg gas." It is characterized by a most disgusting odor, and when inhaled even in small quantities produces severe headaches, nausea, and general prostration; and in large amounts it induces a stupefying effect, which may terminate fatally. This substance is a constituent of the gases of sewers, and sometimes it finds its way into dwellings from defective drain pipes; there, by its soothing effect upon the inmates, its presence is to their senses imperceptible, though its effects are positively deadly.

Carbon Dioxide Exhaled by Human Beings.—Having seen that contamination of air in our dwellings is constantly taking place, it is of interest to inquire as to the rate at which such processes are operating. Many attempts have been made to determine the average quantity of air vitiated by the respiration of a single person during a specified length of time; but the results are widely different owing to to the varying rapidity of the breathing act, and the absence of uniformity in lung capacity. We may safely say, however, as the result of numerous and elaborate experiments, that an adult person of average size in a state of rest, ordinarily expires 0.6 cubic foot carbon dioxide per hour. The amount of this gas naturally present in the outer air is found by analysis

to be about 0.04 per cent., or 0.4 parts per thousand. From the experimental labors of Dr. Chaumont and others, we learn that a disagreeable smell is perceptible in the air of rooms as soon as the carbon dioxide has reached 0.06 per cent., or 0.6 parts per thousand.* This amount, which is 0.2 parts per thousand above that contained in pure air, is considered by reliable authorities as the maximum quantity to be tolerated in the air of inhabited rooms.

Rate of Contamination from Human Respiration—Suppose an adult person to be confined in an air-tight inclosure containing 3000 cubic feet of space. In an hour he would give to the inclosed air 0.6 cubic foot of carbon dioxide; this added to the amount of the gas present in pure air would make the total quantity 1.8 cubic feet, thus:—$0.6 + (0.4 \times 3 = 1.2) = 1.8$. This being distributed among 3000 cubic feet would represent $1.8 \div 3 = 0.6$ cubic foot per thousand, and here we see the permissible limit is exactly reached. In order to keep the air within this limit of impurity, during a second hour 3000 cubic feet of fresh air should be admitted to replace the contaminated air of the chamber.

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*The bad smell here referred to is not due to the carbon dioxide itself, this being an odorless gas, but arises from the foul organic matters of the expired air, and these contaminating ingredients increase in proportion to the carbon dioxide. As no strictly accurate methods of determining the amount of such putrescible substances have been devised, it is a rule with chemists to determine the carbon dioxide in the air under examination, and then to estimate the amount of organic matter from this result.

Amount of Air Required for Efficient Ventilation.—From such deductions as the foregoing, it is stated by many authorities, that to be properly ventilated a dwelling house should receive 3000 cubic feet of fresh air per hour for each of its inmates. This amount may seem excessive; yet in determining it, no allowance has been made for the many contaminating influences beside the exhalations of the occupants. Dr. Billings places the requisite supply of air at one cubic foot per second, or 3600 cubic feet per hour. If fires and lights are burning in the rooms, additional allowance in the supply of fresh air should be made. It is not possible to make an accurate measurement of each of the many sources of contamination; it is necessary, therefore, to make liberal allowance for deficiencies in providing for the air supply of houses. The more closely we can cause the air within doors to approach in composition the atmosphere without, the more beneficial will be its effect upon health. Children expire a lower proportion of carbon dioxide than do adults. Persons engaged in physical exertion exhale much more than the ordinary amount; sick people require a greater supply of fresh air than is indispensable to the healthy. It is therefore plain to us that buildings used for different purposes require varying allowances for the proper supply of air.

Illustrative Examples.—At the rate of contamination already stated, the air in an ordinary bedroom, say 12 by 14 by 11 feet, containing 1848 cubic feet of space, would be contaminated by the exhalations of a

single occupant in a little less than 37 minutes. A school room 28 by 35 by 14 feet would contain 13,720 cubic feet of air. Suppose such a room to be occupied by 60 children, allowing each of them only 2000 cubic feet of air per hour, the contained atmosphere would become vitiated in less than 7 minutes. Fortunately for most of us, the doors and windows of ordinary dwellings are seldom made to close tightly; consequently they permit some passage of air, and the evil results of neglect in ventilation are delayed beyond the theoretical indications.

The Amount of Space necessary to the well being of the inmates of a room is a subject requiring attention. If the space be made inadequately small, the entrance of a proper amount of air within a given time may cause injurious draught.* The figures

* Parkes has furnished us the following good illustration: "For instance, suppose in a dormitory occupied by 10 persons the amount of space per head is only 300 feet; to supply 3000 cubic feet of fresh air per hour, 30,000 cubic feet must be admitted in this period, and the air of the room will be completely changed 10 times, a proceeding which would cause in cold weather, unless the entering air was warm, a most disagreeable draught, for the cold air could not be properly distributed before reaching the persons of the occupants. But if the cubic space per head be 1000 cubic feet, then the air of the dormitory need be changed only 3 times per hour, and if such renewal is effected steadily and gradually, the cold entering air is broken up, and mixing with the warm air of the apartment creates no draught." The same author has drawn attention to the necessity of providing adequate floor space for each individual; "for," says he, "if the height of the room is much over 12 feet, excess in this direction does not compensate for deficiency in the other dimensions, although the total cubic space may be the same; thus it would not be the same thing to allow a man 50 square feet of floor space in a room 20 feet high, as to allow him 100 square feet of floor

already given as indicating the necessary supply of fresh air are based upon the investigations of many leading authorities. On this subject however there is a wide discrepancy of opinion, and some writers give figures which by comparison would seem disproportionately low.* It is well to set our ideal conditions of atmospheric purity fairly high, and then approach them as closely as the prevailing conditions may permit.

Ill Effects of Cellars under Houses.—Another prolific source of contamination to the air of dwellings arises from the hurtful custom of digging cellars beneath the floors of houses. Cellars are usually damp and musty, even if nothing be stored in them; but such places are commonly made receptacles for the most perishable products. The foul gases generated from such decaying matter rise into the rooms above, carrying with them the influences of disease. The earth itself, near the surface, is rich in decomposa-

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space in a room 10 feet high, although the amount of cubic space allotted in each case would be identical. The reason is that the organic matters of respiration are not equally diffused throughout the air of the apartment, but tend to accumulate in the lower strata, consequently excessive height does not, in their case, mean a corresponding dilution."

*Among builders there is a woeful lack of uniformity in ideas as to the requisite air supply for health. The writer has applied to a number of prominent architects for such information, some answers obtained indicated a belief in the figures above quoted; others gave very low estimates. One architect considered necessary 16.6 cubic feet per minute, and one gave 4 cubic feet per minute as a liberal estimate, adding that 4.5 cubic feet would be exceptionally good. Chemical analysis would show the air of occupied rooms so supplied, to be truly filthy, and buildings so constructed are far from healthful.

ble matters, and under the most favorable of circumstances the ground upon which a house rests becomes saturated with the emanations of the rotting contents of the soil. Even upper rooms though they may be properly plastered and floored, soon become foul if not thoroughly aired at short intervals. This is because there are many putresible substances in the earth and upon the walls and furniture of the room, and the products of decomposition accumulate with alarming rapidity, unless adequate provisions be made for their removal.

Vitiation of Air by Combustion—If the combustion of fuel in open fireplaces and in stoves were thoroughly accomplished, the vitiated air would be removed from the room through the draught flue. In the case of artificial lights, however, such as candles, lamps, and gas flames, the products of combustion, together with the nitrogen gas which is left after the consumption of the oxygen, remain in the room. The rate of such vitiating processes depends, of course, upon the substances burned and the rapidity of the combustion. By careful trials it has been found that a pound of good charcoal requires for its complete combustion 11 pounds of air, which amount of air would measure about 150 cubic feet. One pound of mineral coal of ordinary quality requires a little more than $9\frac{1}{4}$ pounds, or about 120 cubic feet of air. A pound of dry wood consumes while burning about six pounds, or 78 cubic feet of air. For purposes of illumination candles are now but little used; their former place being taken by oil lamps and gas

flames. Kerosene lamps vary greatly in the relative amounts of oil which they consume. A lamp of ordinary size will vitiate to an unbreathable state between 70 and 80 cubic feet of air per hour.

A consideration of these facts will indicate the absolute necessity of providing efficient means for a constant supply of fresh air in dwellings.

REVIEW.

1. What are the principal sources of impurity in the air of rooms?
2. Show the contaminating effect of human beings on the air of rooms.
3. Demonstrate that foul matters are constantly being thrown off by the human lungs and skin?
4. Show the value of the sense of smell in warning us against foul air.
5. What do you know of the delicacy of the sense of smell?
6. By what means is the outer air in the neighborhood of dwellings often contaminated?
7. What particular contaminating ingredients are to be found in the air of marshy places?
8. What do you know of sulphuretted hydrogen?
9. Give illustrations of the rate at which contamination of air progresses in closed apartments.
10. State the quantities of air needed per hour for each inmate, for the proper ventilation of dwellings.
11. Illustrate by instances of bed rooms and school rooms of definite sizes, the rate of contamination from the inmates.
12. Show the hurtful effects of placing cellars beneath dwelling rooms.
13. What effect have fires and lights on the air of rooms?
14. Give illustrations of the amounts of air required for the combustion of definite weights of certain fuels.

CHAPTER 6.

ILL EFFECTS OF IMPURE AIR.

The physical operations of which the **Breathing Process** consists are simple. Gaseous matter is taken into the lungs, and after a short time much of it is expelled again. This ingoing and outgoing action might be in some degree imitated by a pair of bellows; here, however, the analogy ends; the air escapes from the bellows unchanged in composition or general properties, but the air exhaled from the lungs is very different from that taken in.

The Respiratory Apparatus.—Let us consider briefly the structure of the respiratory apparatus. A sketch of the principal organs is given in figure 33. The mouth is connected directly with a tube known as the trachea or windpipe, B; this extends downward through the neck into the chest cavity, and there divides, sending a branch, called a bronchus, to each lung. The human lung, like every other part of the body, is of strange and wonderful workmanship; yet simple and surprisingly efficient. The lung, when divested of its delicate wrappings, may be compared to a bag surrounding the bronchus (as at C), so as to appear as an expansion of this tube. By dissecting away the outer portions of the lung, the tube which enters it is seen to divide, and the branches subdivide

again and again, as at D, till they form a net work of tiny tubes, so minute that with our unaided vision we cannot follow them to their terminations. Calling the microscope to our aid, however, we will find that the

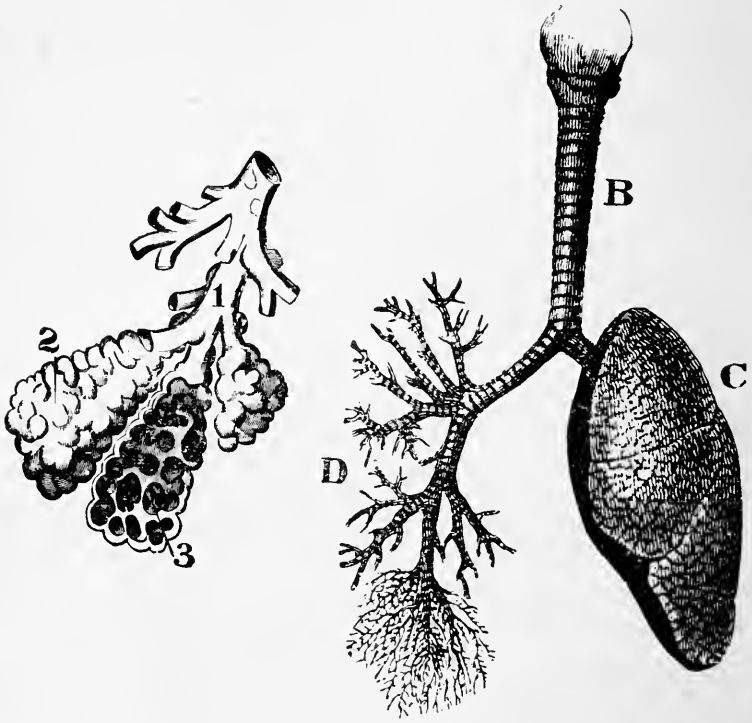

Fig. 33.
Organs of respiration.

finest division of the bronchial tubes 1, terminate in expanded bladder-like inclosures, as in 2. These are called *air vesicles*, and are clustered together in forms suggesting bunches of grapes. A view of the air vesicles laid open is given at 3.

Aeration of the Blood.—During the process of inhalation, air is drawn through the windpipe into the lungs, there filling and inflating the air vesicles. The walls of these vesicles are surprisingly thin, far more delicate in structure than the finest of artificial fabrics. Tiny arteries and veins convey the blood to and from these air vesicles, the vessels spreading over the surface of the vesicles, so that the contained blood is separated from the air only by the thin membranous wall already described. There is a remarkable tendency known as *osmosis*, possessed by all fluids, by which they strive to mix with each other, even if separated by a tolerably thick partition, providing, of course, that the separating medium is at all permeable.

By this property, the air that has been drawn into the vesicles passes through the inclosing wall and mingles with the blood; and at the same time, the foul gases, which have been acquired by the blood in its passage through the system, pass into the cavities of the air vesicles and are expelled from the body in the succeeding exhalations. In this way, the blood becomes aerated or purified by exchanging the gaseous products of disassimilation for invigorating oxygen. Charged with this life-giving ingredient, the blood again goes bounding through the body carrying vitality and energy to every part. If the effete matters resulting from the vital processes were left to accumulate within the body, speedy suffocation would result. They can be removed only by efficient respiration,

taking place through the instrumentality of comparatively pure air.

Morbid Effects of Vitiated Air.—*Scrofula.*—The morbid effects wrought upon the system through the inhalation of impure or vitiated air are very varied. Many specific diseases, and much general debility and predisposition to bodily disorders have been directly traced to this cause. Scrofulous affections are frequently aided in this way. Ills of this class bear evidences of impaired and inefficient nutrition; by this is meant the inability of the body to properly assimilate the elements of food and to produce therefrom healthy tissue. M. Baudoloque, a French physician of high repute and a specialist in scrofulous disorders, writes: "Invariably it will be found on examination that a truly scrofulous disease is caused by a vitiated air, and it is not always necessary that there should have been a prolonged stay in such an atmosphere. Often a few hours each day is sufficient, and it is thus that persons may live in the most healthy (healthful) country, pass the greater part of the day in the open air, and yet become scrofulous, because of sleeping in a confined place, where the air has not been renewed."

Consumption, another dread disease, which carries so many people to their graves, is closely allied in its nature to scrofula.* In consumption, or *Tuber-*

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*"One not very strong or unable powerfully to resist conditions unfavorable to health, and with a predisposition to lung disease, will be sure, sooner or later, by partial lung starvation and blood poisoning to develop pulmonary consumption. The lack of what

culosis, as physicians term the disorder, the lungs of the sufferer develop throughout their tissue, numerous lumpy concretions or tubercles, which consist for the most part of albumen in a coagulated and partially organized form.*

Sore Throat.—A special variety of sore throat, *Tonsilitis*, is recognized by the medical profession as frequently resulting from the breathing of air laden with the products of organic decay. As this disease is of common occurrence among the inmates of houses that are provided with poorly arranged drains, causing a flow of impure gases from the sewer or cess-pool to the rooms of the house, the disorder is frequently

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is so abundant and so cheap—good, pure air—is unquestionably the one great cause of this terrible disease."

BLACK, in "Ten Laws of Health."

*"A great amount of phthisis (consumption) has prevailed in the most varied stations of the (English) army, and in the most beautiful climates—in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda—in all of which places the only common condition was the vitiated atmosphere which our barrack system everywhere produced. And, as if to clinch the argument, there has been of late years a most decided decline in phthisis in these stations, while the only circumstance which has notably changed in the time has been the condition of the air."— *Report of English Army Sanitary Commissioners* (quoted by BLACK).

"Carmichael, in his work on 'Scrofula,' gives some most striking instances where impure air, bad diet, and deficient exercise concurred together to produce a most formidable mortality from phthisis. In one instance in the Dublin House of Industry, where scrofula was formerly so common as to be thought contagious, there were, in one ward, 60 feet long by 18 feet wide, 38 beds, each containing four children; the atmosphere was so bad that in the morning the air of the ward was unendurable. In some of the schools examined by Carmichael, the diet was excellent, and the only causes for the excessive phthisis were the foul air and the want of exercise."—DR. PARKES, London.

called "sewer air throat." "It is marked," says Dr. Parkes, of London, "by great inflammatory swelling of the tonsils, very foul tongue, gastric derangement, accompanied by severe headache and intense depression. The temperature of the body is often not much raised, certainly not to a height proportionate to the severe symptoms; but this low temperature, together with the intense prostration, are characteristic of most illnesses resulting from the entrance of sewer-polluted air or water into the system."

Severe *Dysentery* is frequently caused by the breathing of contaminated air. To this is to be attributed the periodical occurrence of summer disorders of this class, which sometimes produce an alarming degree of mortality. These fatal results are especially marked among children, whose comparatively feeble vitality and tender constitutions can but poorly withstand the death-dealing influences of these foul causes.

Mortality Among Children in Iceland.—It is reported by travelers that the inhabitants of Iceland seem oblivious to the importance of ventilation in their snow huts. Warmth they crave, and this they may secure, though frequently at the expense of life. Dr. Youmans remarks, "We are therefore not surprised that in the foul and stifling air of Iceland habitations, two out of three of all the children should die before twelve days old."*

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*"The extreme cold of the winter in Iceland, reduces the system of domestic ventilation in that country to very primitive principles. A traveler there was so choked one night by the close atmosphere of the air-tight little chamber, in which he slept with

Foul Air Weakens the Entire System.—Beside the few specific bodily troubles named above, out of the many that could be enumerated as resulting from the inhalation of polluted air, the same cause produces a general undermining of the vital powers, and a strong predisposition of the bodily tissues to disease of many kinds. All influences that tend to lower the bodily vitality, weaken our hold on life by inviting disease to take up its abode within our bodies.* An impoverished system is a fertile field for the germination and development of disease germs. It is believed that such germs are widely distributed through the atmosphere, ever ready to enter the human body; yet they flourish within the system only when they find there proper nutriment, such as the impurities attending degenerated tissues and disorganized functions; otherwise they die through lack of nourishment.†

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all the male members of the family, as to be compelled to wake his host, who sprang out of bed at the call, pulled a cork from a knot-hole in the wall for a few minutes, and after replacing the cork, with a shiver returned to bed."

Science, 1889.

*"On the imagination of mothers, educated as well as ignorant, the feeling still seems to be stereotyped, that the free, pure, unadulterated air of heaven falls upon the brow of infancy as the poppies of eternal sleep, and enters the lungs and circulates as a deadly poison; and still the shawls and blankets, sleeping and awake, are pretty generally employed to deprive the objects of the most rapturous, paternal solicitude, of what was originally breathed into the nostrils of the great archetype of the human race as the 'breath of life.'"

(Quoted by YOUMANS.)

† "It was in England that the solution of the great problem of hygiene was first attempted. 'Preventive Medicine' it is there called. Palmerston told a deputation which waited on him in

Effects of Foul Air on the Mental Powers:—The mental powers are greatly weakened and consequently hindered in their proper exercise if foul air be breathed. This would be naturally expected from a consideration of the close relationship existing between the mental and the physical functions of the body. The brain is appropriately spoken of as the organ or seat of the mind; that is to say, though the brain and the mind are in no sense identical, the latter is dependent for its action upon the former, just as the hand in writing is dependent upon the pen. Although the exact relationship between brain and mind are but little comprehended, it is known as a fact that an injury to the brain affects in some degree the mental faculties, and that a strong, well-trained mind is always associated with a properly developed brain.

The brain is composed of nervous tissue, and is nourished by the blood in the same manner as are all other parts of the body. A very large proportion of the blood of the body passes to the brain and is distributed over its surface through numerous minute

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order to ask him to order a fast on the approach of the second epidemic of cholera, to cleanse their sewers and diligently visit the dwellings of the poor. And he did not confine himself to good advice, but with his usual energy he laid his hand on sanitary legislation, and purified the air of London and the large manufacturing towns. The result of the sanitary measures carried out was a reduction of the mortality of London from 26 to 23 per 1,000, and in some of the towns to 17 per 1,000—a low death rate previously only equalled in the Isle of Wight. More than 4,000 lives have been preserved yearly in London, and assuming that the mortality among the sick is 1 in 20, this number represents a diminution in yearly sickness to the extent of 80,000."

DR. SEEGEN.

vessels. As a consequence, the brain is rapidly and strongly influenced by the state of purity in the blood, and as before seen, the blood is greatly affected by the condition of the air employed in respiration. It is clear then that the brain depends largely for its normal action upon the air that is breathed.

Popular Disregard of Requirements for Pure Air.—Yet how oblivious are the majority of people to these vital facts! Even among the noble class of students, old and young, all of whom are supposed to be thinkers, there prevails the most deplorable ignorance; or, if not this, then the most hurtful, almost criminal negligence. The pupil at his books, the editor with his pen, the artist at his easel, and even the theologian asking for divine inspiration in his sacred studies, are apt to voluntarily surround themselves with the stifling, mephitic atmosphere of close-shut rooms. Unto them the air of heaven is forbidden to come.

In places for public gatherings the conditions are even worse. Though architects have now partly learned the lesson of providing adequate avenues of ventilation, thoughtless janitors persistently ignore the means supplied. In the churches and meeting houses dedicated to the worship of the Being who framed the laws of health, and who provided the means for their observance, places in which multitudes gather with the professed desire of hearing and understanding the word of God, the vitiated air begets dullness of intellect and torpor of spirit, and the gentle voice of divine inspiration is unheeded and unheard. Much of the

proverbial drowsiness among the congregations of churches is directly traceable to the closed windows and shut doors of those sacred edifices. Is it other than a grievous sin, a mockery indeed of the Creator's goodness, to petition for the inspiration of His Spirit, and then to willfully darken our minds and bring oblivion upon our souls? The writer has been at night in places of worship in which the lamps burned dimly for want of supporting oxygen; think you the spirits of those present were not correspondingly darkened? Is Godliness to be attained in the midst of willful and persistent uncleanliness?

REVIEW.

1. Describe the processes of human respiration.
2. Describe the organs of respiration.
3. Explain the effect of pure air upon the blood in the vessels of the lungs.
4. State the principal diseases which are particularly favored by the breathing of foul air.
5. What do you know of scrofulous disorders being aided by vitiated air?
6. Of consumption?
7. Of tonsilitis?
8. Show the effects of foul air in inducing general disposition of the bodily tissues toward disease.
9. Give instances, from among those quoted, of the baneful effects of contaminated air.
10. What have you heard of the inefficient ventilation practiced in Iceland, and of the high rate of mortality there prevailing among children?
11. What effect has impure air on the mental powers?
12. Explain the physiological effects of foul air upon the brain.

CHAPTER 7.

DUST IN THE AIR.

Dust Floating in the Air.— The principal gaseous and liquid impurities of the atmosphere have been dwelt upon in a previous chapter, but in addition to the contaminating substances there named, there are others, consisting of finely divided, solid particles. The name commonly applied to this class of impurities is dust. Until recently, but little thought was bestowed upon the ill effects of these floating particles; of late, however, the subject has received greater attention. It has been conclusively proved by experiment and observation that the inhalation of dust-laden air is a potent factor in the production and growth of certain disorders of the respiratory organs, among which bronchitis, pneumonia, and phthisis are prominent. The presence of dust within the respiratory passages will invariably produce serious results, owing to the irritating effect of hard particles upon the delicate lung tissues.

Dust Inhaling Occupations.—To illustrate the effect of dust upon the respiratory organs, let us consider briefly the effects of some particular branches of dusty toil. Dr. Hall tells us that the average life of fork grinders is about twenty-nine years, and that of edge-tool workers generally about thirty-one years, the cause of death in the majority of cases being lung

troubles, induced through the inhaling of metallic particles and the dust arising from the wear of the grindstones. Pearl button makers suffer from such disorders to a marked extent, as do also workers of flax and cotton, and employes in paper factories.

Hard and Irritating Dust Most Injurious.—An attentive review of statistics representing the comparative mortality among people of different dusty occupations, reveals the fact that the most injurious kinds of dust are such as consist of hard, sharp, and angular pieces. Dr. Ogle, of England, has compiled a table* showing the mortality among British people (males) between the ages of twenty-five and sixty-five years, who are employed in certain widely different occupations, including those of (1) coal miners, (2) carpenters, (3) bakers and confectioners, (4) plumbers, painters, and glaziers; (5) masons and bricklayers; (6) wool workers; (7) cotton workers; (8) quarrymen (stone and slate); (9) cutlers; (10) file-makers; (11) earthenware manufacturers; (12) Cornish tin miners.

Comparative Mortality among Coal Miners and Tin Miners.—It is found that these trades stand in the order in which they are given above in the scale of increasing mortality among their followers; that is to say, among the people employed in the occupations named, the English coal miner is freest

* Published as a supplement to the Forty-fifth Annual Report of the Registrar-General of England. For quotations and comments see "Practical Hygiene" by Dr. Louis C. Parkes, London.

from lung disorders, and the Cornish tin-miner is of all most subject to such troubles. Indeed the mortality from lung diseases alone among the miners of tin ore is 3.5 times that among the coal diggers; nearly 66 per cent. of the total mortality among tin-miners is due to bronchial disorders, and the death-rate among this class of workmen is nearly three times as high as that of the male population of their region considered as a whole.

Dr. Ogle attributes the comparative safety* of coal miners in this respect, mainly to the softness of coal-dust particles and to the freedom of such from all sharp angles and points. He believes also that coal-dust exercises some influence in hindering the progress of phthisical disorders. Such comparative immunity from lung diseases among the miners of coal, is still more surprising when we consider that these men are kept while at work in a heated atmosphere, vitiated from constant emanations of noxious gases from the walls, ceilings, and floors of the black, subterranean passages.† The tin-miners on the other hand, though

* The reader should guard himself against an exaggerated opinion of the safety of coal-miners. The immunity spoken of in the text has reference to lung diseases only, and the comparison is made with other dust-inhaling occupations only. The miner of coal is certainly far more liable to bronchial troubles than persons protected from all dust would be. That coal mining is a hazardous occupation from liability to terrible accidents needs no argument here.

† Let it be remembered that these statements regarding the healthfulness of coal-miners are applied to the workers of British mines only. The laws of England regarding the ventilation of mines, especially coal-mines, are strict. The copious flow of air through the underground passage carries away noxious gases and dust as fast as liberated.

laboring under many conditions similar to those attending the coal workers, inhale dust consisting of hard, sharp, and irritant particles.

Poisonous Dust.— These examples illustrate the mechanical irritation on the walls of the air passages occasioned by dust, much of which, in a toxical sense, may be considered innocuous; there are other occupations, however, in the course of which the workmen are exposed to poisonous dust. Such is the case with brass founders and copper-smiths, among whom mortality runs high from copper poisoning; "brass-founders' ague" used to be a popular name for disorders of this sort. Lead poisoning is a frequent cause of death among plumbers and painters, the former contracting the disease from the inhalation of volatalized lead and lead oxide, and the latter from breathing air laden with white-lead dust, and from absorbing through the skin the poisonous lead compounds of their paints. Mercurial poisoning causes a rise of mortality among all who work with the curious quicksilver, and arsenical fumes carry many to early graves from the ranks of ore roasters.

All Dust Deleterious.—The cases already referred to are somewhat special in their nature, it is true; comparatively few are called to labor and to suffer in such injurious occupations; yet there are lessons in these examples which are applicable to all people. We learn that dust of any description is deleterious when introduced into the air passages of the body; care, therefore, should be exercised to escape the injuries thus indicated.

Inhalation Through the Nostrils.—The Creator has done much to arm His children against these inevitable dangers. Our nostrils are lined with stout hairs, *vibrissæ* they are called, and these act somewhat as a sieve to the air that passes between them. The nose openings are the proper respiratory entrances to the lungs; and much of the dust, which, if breathing be carried on through the mouth, will surely find its way into the deeper air passages, will be arrested in its course if forced to thread the intricate passages of the nose. When a person is exposed to dust, the mouth should be kept closed.

Lining of Respiratory Passages.—Further defense against the injuries of dust-laden air is offered by the peculiar structure of the lining membrane in the trachea and the lung passages. The inner surface of these channels is ciliated—that is, covered with innumerable hair-like outgrowths (cilia), so fine as to appear under the low powers of the microscope like the pile on new velvet. These countless cilia are in a state of constant motion, like waving grain under the influence of a gentle breeze, and as the direct movement is always toward the mouth, there is a tendency to sweep upward from the lungs all solid particles that may have found lodgment upon the walls. When the dust thus carried reaches the throat, a cough suggests itself, an expectoration follows, and the intruding particles are ejected from the body.

Inanimate Components of Dust.—It will perhaps be interesting, and certainly instructive, to inquire

as to the nature of common street dust. Its grittiness declares the presence of earthy particles, such as bits of pulverized stone; this material is a natural consequence of the wear and tear of roads, and the more general disintegration of the rocks through natural agencies. But beside this purely inorganic or mineral matter, the microscope reveals many organic particles. Mingled with the structureless mineral particles are the siliceous shells of diatoms; also spores of many of the lower plants; fragments of straw and hay,—these often partly digested, proving that they must have traversed the alimentary tract of some herbivorous animal;—grains of starch; scales from the wings of butterflies and moths; hairs of animals, and soft down from birds; and bits of cotton, wool, and silk.

Living Organisms in Dust.—In addition to this varied assortment of inanimate matter, the microscope reveals the presence of many living organisms, whose minuteness is almost beyond description. Many of these are comparatively innocuous, though some have the power of producing specific diseases, provided they are taken into the system, and find there the nutriment necessary to their being. Such germs thrive within the body chiefly upon the products of deteriorated tissue; a healthy system has power to resist the attacks of many noxious germs by refusing to afford them requisite nourishment. The person who has ignored God's law of health, and who has weakened his body through injurious excesses, has little means of defence against the invading hosts of contagious

germs. Temperance in all proper indulgences, and rectitude in all the duties of life, will combine their unconquerable forces against the deadly foe.

Household Dust.—Much of the outdoor dust finds its way into the house, and there augments the ills resulting from the presence of household dust proper. The oft-quoted illustration is conclusive proof that dust pervades our homes—notice the path of a sunbeam within a partially darkened room; along the line of light innumerable "gay motes" appear, rising, sinking, with ceaseless motion, all made plain to our gaze by that efficient analyist, the solar beam. Professor Tyndall has employed the electric arc instead of sun light in numerous investigations, and has clearly shown that the air in all places near the earth's surface is heavily dust-laden. The dust of rooms comprise all the ingredients of street dust, and in addition many other particles arising from household wear and tear and the varied domestic operations. Common among these are fibres of many kinds from the carpets and draperies of rooms; crystals of salt; finely divided carbon as soot, lampblack, and coal-dust; bits of hair and wool; and epithelial scales from the skin and lungs of the inmates. Of these, the last named, including all organic particles* arising from the bodies of living beings, are most to be feared. Such organic

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*Dr. Louis Parkes says of household dust: "It is thus seen to consist largely of organic refuse, often more or less putrescent, and its presence in the air assists in the production of the low state of health so common to the occupants of dirty, overcrowded houses."

dust, if arising from the bodies of persons suffering from infectious diseases, may become the medium of deadly contagion.

Dust-traps in Houses.—It is, of course, impossible to prevent the entrance and formation of dust within our homes; the necessary wear of domestic operations will constantly give rise to detached particles; we can scarcely hope to find a dustless house. Our efforts would be most wisely directed if applied toward the prevention of undue accumulations of the dust, and to averting, as best we can, the ill effects of its putrefactive changes. Many rooms are, from their construction, veritable dust-traps. Uneven wall surfaces, projecting door and window frames, cornices, ceiling and wall mouldings, all prove effective in entrapping dust particles and holding the same secure from the broom and duster of the most energetic house-maid. The floors are no less instrumental in this respect; crevices between the boards hold immense quantities of dust; heavy and immovable furniture renders a thorough and frequent cleansing scarcely possible; but beyond all these, carpets stand forth as the chief of dust-catchers.

Carpets and Curtains as Dust Holders.—The custom of covering every floor with woven carpets, which are removed only at intervals of months, is a deplorable one. Investigation by several English physicians has done much to prove this fact, and there are today many eminent medical practitioners who decline to undertake cases of illness if the patients are kept in carpeted rooms. Close and polished

or oiled floors are easily cleaned; if carpets are used at all they should be but lightly fastened. Indian matting has been recommended; this material is but slightly absorbent, and admits of ready cleansing. Oil cloth and linoleum may be used in dry situations; if the floors are exposed to dampness, however, the use of such will favor the development of "rot" in the wood.

Curtains of thick fabrics, heavy draperies, wall hangings, lambrequins, and the like, all serve to gather and conceal dust. If such decorations are used at all they should be of light material, and be so arranged as to admit of ready removal and frequent cleansing.

Poisonous Wall Papers.—Rough or "flock" wall papers hold large quantities of dust, and some such papers give off particles of pigment from their own surfaces. This condition is especially undesirable if the loosely applied coloring matters of the paper are of a poisonous nature. Much has been written and said regarding the presence of arsenic in wall papers, and the deadly effects of the poison upon the inmates of rooms ornamented with such papers. Doubtless, the use of arsenical wall paper is a source of serious danger, and has produced even fatal results, but papers of this sort are far less common than has been generally supposed.* The writer has collected

*Arsenic and various other poisonous matters are used in coloring many kinds of paper besides that designed for wall decoration. Even the tinted tissue paper used for the instruction and entertainment of children in kindergartens, is contaminated with poisonous colors, and cases of serious injury have resulted from the children's habit of chewing such paper. It may

from the supply stores of Salt Lake City, and has analyzed 127 specimens of wall papers, of as many colors and kinds as could be found; and in only four of them was arsenic present at all. The worst of these was a bright green with gilt markings; this contained per square foot between 7 and 8 grains of metallic arsenic, corresponding to nearly 10 grains of white arsenic. The use of such a paper on the walls of dwelling rooms would be a source of great danger.

Arsenical Poisoning from Wall Paper.—Parkes reports the presence of arsenic in wall papers in quantities varying from less than a grain to even 60 grains per square foot. The same authority has classified the principal symptoms of arsenical poisoning from such cause, among which the following are prominent:—cough associated with nausea, diarrhœa, colic pains and cramps, dryness of mouth and throat with intense thirst, severe lachrymation, distressing headache, and a marked debility of the whole system, which, in extreme cases, leads to actual paralysis of the limbs sometimes followed by convulsions and death.

Arsenical Pigments.—Green papers are the ones most likely to contain arsenic, though the poison has been found in reds, browns, and greys. The arsenical compound most used as a pigment is the arsenite of

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be argued that paper should not be chewed; this is true, but many children will try their teeth on everything that they can get into their mouths. If paper contains poisonous pigments, as Dr. Youmans has said with a kind of grim humor, "such deadly additions utterly spoil the paper for dietetical purposes either for children or adults."

copper, commercially known as "Scheele's green," and composed of arsenic and copper in a combined form: a still more attractive tint is produced by the aceto-arsenite of copper, commonly known as "Schweinfurth green." Some arsenical papers have the coloring matters so loosely applied that the poisonous particles become detached from the paper and permeate the room as fine dust, thus finding their way into the lungs of the inmates through the process of respiration. In other cases, especially if exposed to dampness, the arsenical compounds rapidly undergo chemical changes whereby certain gaseous substances are generated, the chief of which is arseniuretted hydrogen—one of the deadliest of poisons.*

Characteristics of non-injurious Wall Paper.—A competent chemist could determine by very simple tests whether arsenic is or is not present in any samples of paper submitted to him; if the means of securing such a test be not at hand when selections of wall paper are to be made, it would be safest to choose smooth papers, of light tints, with colors that cannot be easily rubbed off. Varnished papers are still better; their colors are protected beneath a tolerably impervious coat, and they admit of washing.

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*Prof. Johnson of Yale says that Schweinfurth green when moist gives rise to the formation of the deadly arseniuretted hydrogen in great quantity. He has given a detailed account of the poisoning of a whole family from sleeping in a house, the walls of which were hung with paper of this dangerous though beautiful tint.

REVIEW.

1. What is dust?
2. What effect has dust upon the respiratory passages when inhaled with the air?
3. What do you know of the unhealthfulness of certain dust-inhaling occupations?
4. Explain Dr. Ogle's example of the difference between English tin-miners and coal-miners in their liability to lung troubles.
5. Give instances of the ill effects of dust in the case of fork and tool grinders.
6. Give instances of the effects of inhaling poisonous dust.
7. What natural barrier against the entrance of dust into the lungs has the Creator provided?
8. Explain the action of the cilia in the bronchial passages.
9. What do you know of the composition of out-door dust?
10. Of in-door dust?
11. What is meant by organic dust?
12. Name the principal features of ordinary dwellings which favor the accumulation of dust.
13. Show the effect of carpets as holders of dust.
14. What are the dangers of poisonous pigments in wall papers?
15. What do you know of the occurrence of arsenical pigments in wall papers?
16. State the principal properties of a good wall paper.

CHAPTER 8.

VENTILATION.

Methods of Purifying the Air of Rooms.—Having convinced ourselves that the atmosphere of dwellings is constantly becoming contaminated through additions of foul and poisonous matters, it is now a matter of importance and interest to consider the principal conditions attending the necessary purification of the air of our homes. Two general modes of accomplishing this have been attempted. The first consists in removing the vitiated air, and admitting in its place a supply of fresh air from without; this is commonly spoken of as *ventilation* proper. In the second method, chemical means are employed either to decompose or to absorb the effete matters as fast as they are formed, thus maintaining in the inclosed atmosphere a normal state of purity; this is known as the *chemical method.* Of each of these general processes there are numerous variations as to details, but the chemical method has had but limited application; we shall therefore consider here only the more important methods pertaining to ventilation proper.

Requirements in Efficient Ventilation.—In devising plans for the ventilation of buildings, we are required to provide for the removal of foul air as fast as formed, and for its replacement by pure air from without. Attention must also be paid to the temperature of the entering air, for experiment and observation have shown that the introduction of large volumes of cold air into inhabited rooms may prove a source of

serious injury. Draughts are also to be avoided, else ill effects will be manifest in the health of the inmates.

The frequent changing of the air of an apartment involves the moving of immense masses of air, and some adequate power is requisite to the accomplishment of this. The means generally employed are dependent (1) upon the *heating of the contained atmosphere*; or (2) upon *mechanical devices*. It will be well to consider a few methods from each of these divisions.

1.—AIDS TO VENTILATION, DEPENDING UPON TEMPERATURE CHANGES.

Currents Produced by Changes of Temperature.—It has long been held as an adage that "Heat causes expansion, and cold causes contraction." This is applicable to gases as well as to solids and liquids. When a mass of air is warmed, its particles are driven farther apart, thus requiring greater space; the warmed air is specifically lighter than the cold, and consequently tends to rise; this movement would produce an empty space or partial vacuum below, but the neighboring cold air promptly rushes in to fill such space. All natural movements of air, which we call winds, depend directly or indirectly upon this cause. Any means of warming and expanding the air in one place will cause there a rising current, and the space below will soon be filled with air of a lower temperature, which in turn will become heated, will rise, and will make room for other air. This principle may be well observed in the entering and out-going currents of a room. If the temperature of the inclosed air be higher than that

without, when the door is opened the cold air will enter in a current near the floor, while the warmed and lighter atmosphere will pass out by a counter current at the top. To make clear the course of these currents, place the door ajar, (see figure 34) and hold a lighted candle in the opening, first near the top, and then below. The flame will be driven outward at the top, and toward the room at the bottom.

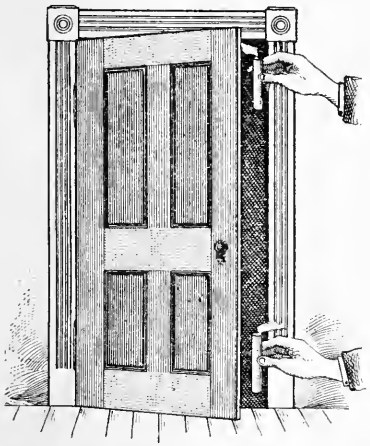

Fig. 34.
Currents into and from a warmed room.

On warm days of summer, or at other times by artificially cooling the inclosed air, these conditions of relative temperature within and without may be reversed; then the outer air, being warmer than the inclosed, would enter near the top of the door opening, while an out-going current would be established below.

Opposite Currents Essential to Ventilation.—In the experiments just described, the width of the door opening permits the passage of currents in opposite directions; with more contracted spaces, however, such counter currents would seriously interfere with and perhaps totally neutralize each other. To illustrate this, provide a small flame, as that of a burning candle; surround this with a good sized lamp chimney, set in a shallow dish containing a little water so

as to seal the bottom. The flame soon dies out, smothered by the non-supporting products of the combustion. Now divide the chimney passage by inserting a strip of metal, thin wood, or even of stiff paper, as shown in figure 35, the candle may now be kept burning. A bit of smouldering paper held at the top will show the existence of upward and downward currents. This clearly demonstrates the necessity of providing separate openings as inlet and outlet for the air of any room.

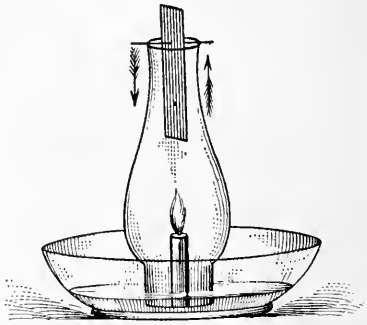

Fig. 35.

Opposite currents in a divided channel.

Ventilation in Mines.—Upon this simple principle the ordinary systems of mine ventilation are founded. In the case of a deep mine, it is usual either to sink two shafts or to construct a bratticed single shaft. The underground passages are so connected as to form a series of uninterrupted channels from one shaft to the other, see figure 36. As long as the air remains at the same temperature in both, no movement will take place; but by placing a fire at the bottom of one shaft, the air column above becomes expanded, and rises; this upward movement is balanced by a corresponding downward current through the other shaft. By such means effective ventilation is maintained.

Lyman's Ventilator.—A principle exactly opposite to that of creating upward currents by means of

heat has also been practically applied. This consists in causing a descending current by cooling the air above. Upon this principle Lyman's ventilator (figure

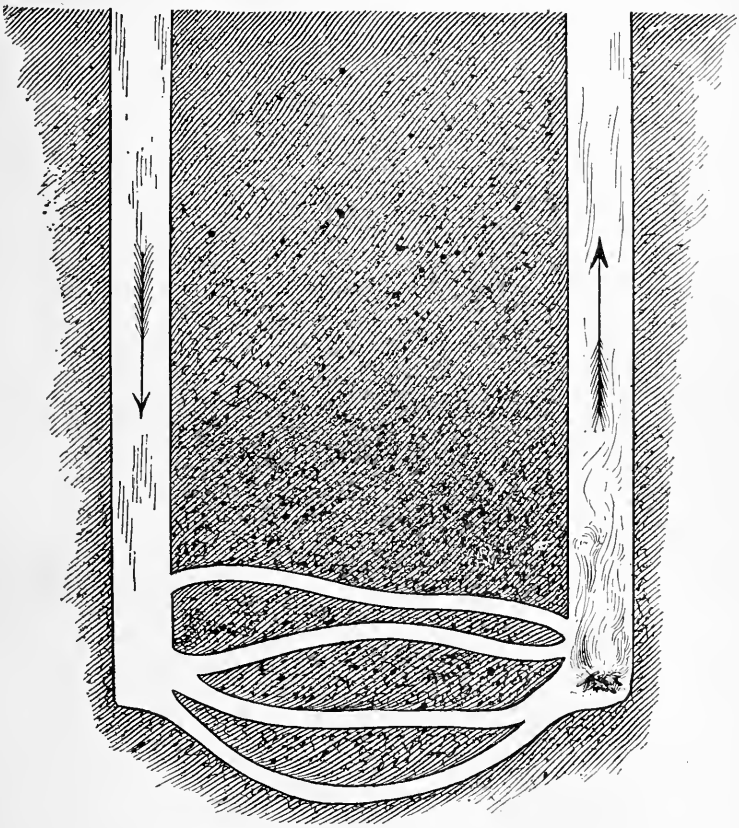

Fig. 36.
Upcast and downcast currents in a mine.

37) is constructed. This device consists of a box containing ice (*a*); the bottom (*b*) is perforated, and a gutter and waste pipe (*c*) are arranged below, to catch the water from the melting ice; a large flue (*d*) conducts the cold descending air into the rooms; an

upper box (*e*) usually made of wire, contains charcoal, which serves to purify the entering air and also to retard the melting of the ice.*

Currents in Rooms.—Even within closed rooms, moving currents with consequent draughts are frequent. During cold weather the windows are considerably colder than the thicker walls, consequently the inside air in contact with the cold glass becomes chilled and falls; while a warmed current from other parts of the room sets in to fill the space vacated by the descending cold air. A person sitting by a window under such circumstances would be entirely enveloped in the falling cloud of cold air, with great detriment to his health. To lessen this danger, builders now plan *double windows* consisting of an outer and an inner sash, with a few inches space between. The air within this space serves as

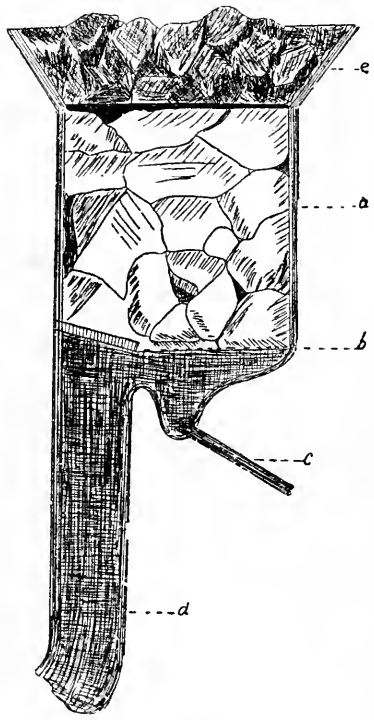

Fig. 37.
Lyman's ventilator.

* Youmans says of this ventilator: "This arrangement on a small scale has been mounted on secretaries, to secure a cool and refreshing air while writing; over beds to cool the air while sleeping; and over cradles to furnish pure air for sick children."

a non-conducting wall separating the outer cold atmosphere from the warmer air of the room. By holding a candle flame near the windows, and alongside the walls, the presence of complicated currents within the room will be at once revealed. Most of the simplest methods of ventilation are associated with the means of warming the apartments; indeed the subjects of ventilation and warming are so closely related that to consider them independently of each other would be almost impossible.

Fires as Aids to Ventilation.—A good fire in an *open grate* necessitates an ample chimney draught; the rising current within the flue exerts a powerful aspirating effect, which results in the ready removal of air from the room. A corresponding quantity of outer air must enter, to replace that which has been taken away. This incoming air causes a powerful current through the room toward the grate; indeed, in the case of the wide open grates of olden times, the draught was so strong that our worthy ancestors found it necessary to provide specially constructed seats, called settles, with high, close backs, for use before their roaring fires. In comparison with these huge fire places, capable of admitting the Yule logs without difficulty, the open grates of modern times seem very much contracted; the space above the fire bars,—and this largely determines the aspirating power of the grate,—being now reduced to the smallest possible dimensions. Many forms of *ventilator-stoves* have of late appeared for sale. Such a stove is constructed with a double casing; air enters below,

and after becoming warmed it escapes into the room through a perforated top. This subject of house warming will receive attention in a subsequent chapter; (chap. 12).

Chimneys and Double Flues.—The aspirating effect of a chimney increases in proportion to the energy of the fire; though observation has proved that a decided draught is noticeable in chimneys even when no fire is in the grate. If a chimney be constructed with a double flue, one division may be used specially as a ventilating shaft; the air within it, being warmed through proximity to the heating flue, will rise with vigor. An objection to the use of double flues has been found in the fact that, if of improper construction, or if there be no adequate inlet for air to the apartment, they are apt to permit downward currents, and thus to draw into the room smoke from the fire flue.

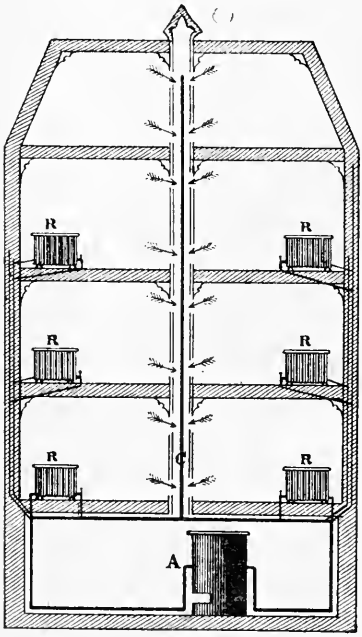

Fig. 38.
Gillis system of ventilating.

Flue Registers. — The apertures that lead from the room into the flue are usually guarded by adjustable registers, the commonest form of which consists of an iron grating and a movable back, so arranged that the passage may be opened

or closed at pleasure. The efficiency of such a register may be greatly increased by attaching to the inside of the bars a flap of thin oil cloth or of oiled silk; this will yield to pressure from the room toward the chimney, but the least impulse in the opposite direction will push the curtain into close contact with the inside of the register, thus preventing the entrance of back currents into the room. Perhaps the best contrivance of the kind is the *Arnott valve*, which consists of a movable door of metal, set in the chimney aperture, and so delicately adjusted as to yield to the slightest current toward the chimney, and to close firmly and easily when pressed in an opposite direction.

Ventilation by Steam Warming. — For the ventilation of large buildings, many devices depending upon the expansion of air by warming have been proposed. A very efficient method is known as the *Gillis system*; this, however, can be used only in steam-warmed buildings. As is shown in figure 38, a large shaft extends from the lowest floor upward through the roof. Up the center of this shaft a steam pipe is carried from the boiler A. In each room, two openings, one at the top and the other near the floor, communicate with the shaft; these apertures are provided with registers and automatic valves. The heat of the steam pipe causes a powerful upward current, by which air is drawn from the rooms. Steam radiators R, for warming the rooms, are supplied on each floor.

2.—MECHANICAL AIDS TO VENTILATION.

Currents from Fans.—Many forms of air-pro-

pellers have been proposed for purposes of ventilation. Most of them possess some merit, and some of them rank among the most efficient of ventilators. The *exhaust fan* (figure 39) seems to be a favorite device. Dr. Mott speaking of the Blackburn fan, one of the most efficient kinds, states that a single 48 inch fan, if made to run at the rate of 500 to 600 revolutions per minute, will carry off 30,000 cubic feet of air per minute. Large fans, for the ventilation of buildings are usually operated by steam or water power; electric dynamos however may be used as a source of power. For producing air currents in small apartments, small portable fans set on ornamented stands, and operated by primary currents from local electric batteries, are now in common use. Such fans may be operated on tables, and desks, and over sleeping couches.

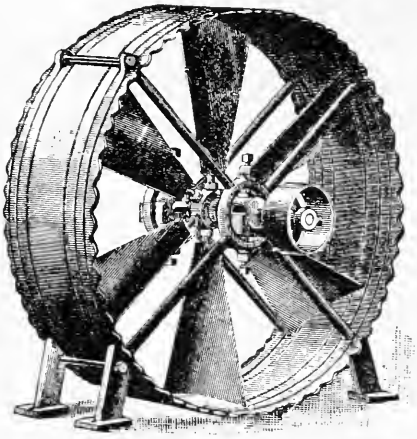

Fig. 39.
Exhaust fan.

Revolving cowls on chimney tops, if properly constructed, serve to increase the aspirating effects of chimney flues.

Pipes as Inlets for Air.—Thus far our attention

has been applied to methods for removing the foul air from rooms; adequate means for introducing a supply of fresh air are also to be considered. Many common forms of inlets are objectionable because of the injurious draughts to which they give rise. In the ventilation of large buildings, pipes are often employed for conveying air to the interior; these can be easily operated with good results; but in small dwellings, windows and transoms are usually relied upon for admitting air. Where inlet pipes are used, however, a great advantage is possessed in the ease with which the incoming air may be warmed. The pipes may be passed through a heating box connected with the furnace; and if the air thus warmed be found deficient in moisture, evaporating pans of water may be placed in the course of the stream.

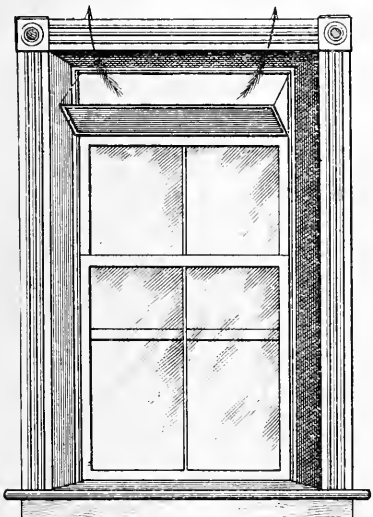

Fig. 40.
Entering current of air deflected toward ceiling.

Window Currents, Ordinary and Deflected.—By opening the upper sash of a window, a strong entering current may be established. The cold air, however, will fall rapidly, without diffusing itself sufficiently throughout the room. If there

be a fire in the room, this current of cold air will continue its course to the grate, and thus be speedily taken from the room, having served but little the purposes of ventilation. It has been proved to be advantageous to place a board at an angle on the upper part of the sash, so as to deflect the entering current toward the ceiling (see figure 40.)

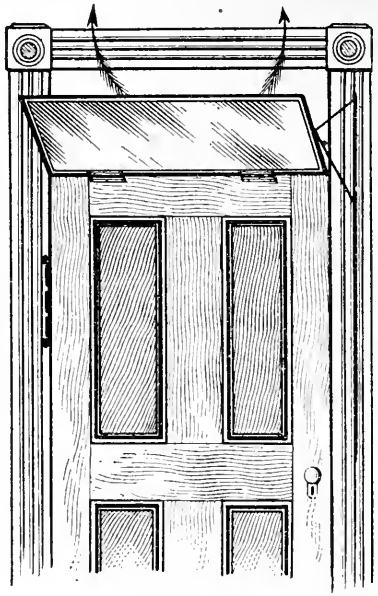

Fig. 41.
Transom hinged so as to deflect air currents toward ceiling.

On the same principle, the efficiency of *transoms* may be greatly increased by hinging them at the bottom, so that they may be set obliquely toward the ceiling, as in figure 41.

Currents Between Window Sashes.—With ordinary windows it is a good plan, and one that is widely practiced, to raise the lower sash, and place beneath it a strip of board from four to six inches wide and of length sufficient to extend across the window opening, see figure 42. This leaves a space between the sashes, through which air will enter the room, the current being directed upward. Before falling, the fresh air will have been diffused.

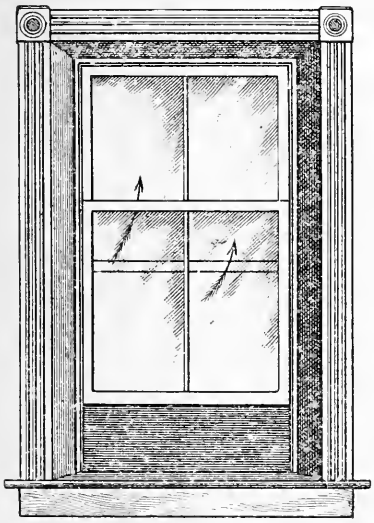

Fig. 42.
Currents entering between window sashes.

Diffusing the Incoming Air. — It is possible to utilize windows both as inlet and outlet air passages. For breaking up the entering current so as to aid in its diffusion, sheets of finely perforated metal may be inserted in the upper sash in place of the ordinary glass panes, or gratings with inclined slots may be used to advantage.

REVIEW.

1. What is ventilation?
2. State the two general modes of purifying the air of rooms?
3. What powers are usually employed in changing the air of rooms?
4. Show the value of temperature changes in moving the air of apartments.
5. Illustrate the entering and out-going currents of a room with the door placed ajar.
6. Fully explain the need of double passages in the case of a candle burning within a lamp chimney.
7. How is this principle applied to the ventilation of mines?
8. How may descending currents of air be produced by cooling?

9. Describe Lyman's ventilator.
10. What is the effect of double windows in maintaining an equal temperature in rooms?
11. What is the value of fires in open grates in providing ventilation?
12. What do you know of the value of double flues in heating and ventilating rooms?
13. Explain the operation of the Arnott valve in ventilating flues.
14. Explain the Gillis system of ventilation.
15. Name the principal mechanical aids in ventilation.
16. Explain the value of the exhaust fan in ventilating.
17. State the essential features of a good inlet for air to a room.
18. How may the incoming air be properly deflected upward?
19. Show the value of windows as inlets for air.
20. Explain the use of transoms as inlets.

CHAPTER 9.

SOME PROPERTIES OF HEAT.

The close relation existing between the processes of ventilation and those of house warming has been already mentioned. Incidental reference has been made to some methods of domestic warming, but before attempting any detailed consideration of the subject, it will be well to turn attention to some of the simple principles by which the form of energy known as heat is controlled.

Nature of Heat.—Heat is that force which, when operating upon the nerves of the living body, produces the sensations of warmth and cold. The true nature of heat, as indeed of all other forms of force, is very imperfectly understood by mankind; but it is a general belief among experimenters and thinking men, that heat in a body is the manifestation of motion among the particles. The plausibility of this view is strengthened by the fact that motion may be transformed into heat; and conversely, heat may be made to originate motion, with but little unaccounted loss of energy in either case. There is good reason for believing that as a body grows warm its particles are made to move, within certain limits, with increasing speed, and that at the same time they are driven farther apart, and thus the size of the body is increased. In the case of a fusible solid, iron for example, the temperature may be raised till the particles are so far separated that their cohesion is greatly diminished, and

the liquid state results. If the molten material be still more highly heated, the gaseous condition may be reached, the vapor of iron thus produced corresponding in physical state to steam.

Expansion of Solids by Heat.—The general effect of heat when applied to bodies is to cause expansion. This is true of solids, liquids, and gases. Figure 43 illustrates a common experiment upon this point. A ring and a ball of metal are provided; they are of such relative sizes that the ball while cold will readily pass through the ring. By heating the ball, however, it becomes enlarged, and will no longer pass through the ring. The blacksmith applies a practical knowledge of this principle when he heats the tires of wheels before fitting them about the felloes; the iron, he knows, will contract in cooling and thus the tires will fit the more tightly.

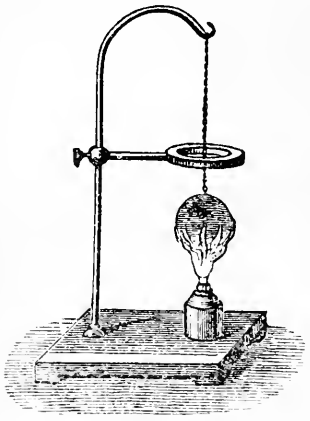

Fig. 43.
Ball enlarged by heat.

The Pyrometer.—The apparatus shown in figure 44 serves to demonstrate very plainly the expansion of a solid by heat. A bar of metal is supported on two pillars, one end of the bar is firmly held by a screw; the other end, which is free to move, rests lightly against a lever, and this is attached to a pointer which moves over a graduated arc. As the bar is heated by lamps placed beneath, it elongates and thus moves the

index finger. An instrument of this kind is called a "pyrometer," the word meaning a measurer of heat or of fire. Pyrometers are used to measure very high

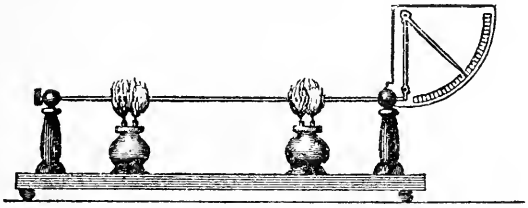

Fig. 44.
Pyrometer.

temperatures; such as the heat of a furnace. Ordinary thermometers would be destroyed by such great heat.

Force Exerted by Expanding Solids.—The force exerted by the expansion of solids through increasing temperature, is enormous. The iron rods and cables of which suspension bridges are made, move through considerable distances in the course of a season's range of temperature.* A difference of 81° F. between summer and winter temperatures is by no means uncommon; yet such a change operating on a bar of wrought iron 10 inches long, would increase its length 1–200 inch; this force is equivalent to a strain of 50 tons. It has been shown by careful trial, that a bar of iron measuring 1 square inch in cross-section, in being warmed from the freezing point to dull-red

*Of the Brittania bridge an observer has said, "The ponderous iron tubes writhe and twist like huge serpents under the varying influence of the solar heat. The span of the tube is depressed only a quarter of an inch by the heaviest train of cars, wh un lifts it two and a half inches."

heat, will elongate about 6–1000 of its original length. The mechanical strain needed to stretch such a bar to this extent is about 90 tons.

Effect of Temperature Changes on Pendulums.—Many practical illustrations of this principle may be observed in household operations. The pendulum rod of a clock elongates during warm weather and shortens during the cold season. Now the office of a clock pendulum is that of a regulator to the time piece; by its swinging it controls the speed of the machinery. Observation proves that a long pendulum requires a greater time to vibrate than does a short one. In warm weather, therefore, the pendulum is apt to swing more slowly and thus cause the clock to fall behind time. In cold weather, on the other hand, the fast-moving pendulum causes the clock to run ahead of the true time. These irregularities may be in some degree corrected by raising or lowering the pendulum "bob" in accordance with the prevailing conditions of temperature.

Some pendulums are so constructed as to partially regulate themselves; these are known as **compensation pendulums**, the simplest of which is the *gridiron pendulum*, sketched in figure 45. The pendulum rod consists of bars of two different metals, usually steel and brass, so arranged that the bars of one material can elongate only in a downward direction, they being fixed above; while the other bars can expand only in an upward direction. Thus the upward and the downward expansion may be made to compensate each other.

Another form of compensation pendulum is the *mercurial bob pendulum*, shown in figure 46. In this the lower part of the pendulum consists of a frame-work or box, within which are set a number of glass vessels, containing mercury. Two such vessels are shown in the figure. As the pendulum rod elongates through increasing temperature, the mercury in the open vessels also expands and consequently rises. These opposite expansions may neutralize each other's effect, and the "center of oscillation," which determines the true length of the pendulum, may remain unchanged.

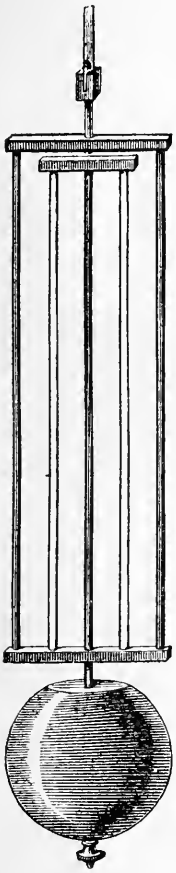

Fig. 45.
Gridiron compensation pendulum.

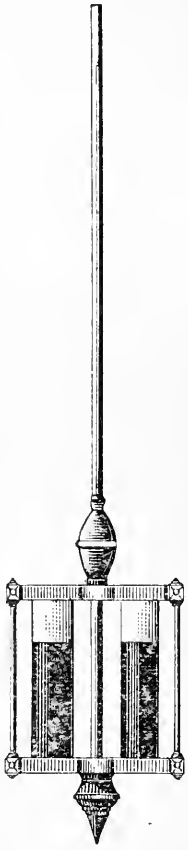

Fig 46.
Mercurial pendulum bob.

Expansion of Fluids by Heat.—Although we observe fewer illustrations of the expansion of liquids and gases under the influence of heat, yet careful experiment will show that these bodies too, obey the general law. To show the expansion of liquids under the influence of heat, take a

glass bulb attached to a stem, or a small glass flask as in figure 47, provided with a tight-fitting cork through which passes an open tube; fill the vessel with water and gently warm. The liquid rises in the tube under the expansive influence of the heat.

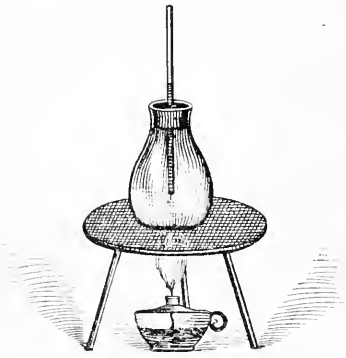

Fig. 47.
Liquid expanding by heat.

To demonstrate the expansion of gases, take a similar bulb or flask, empty and dry; invert and place the stem in a vessel of water (see figure 48). Grasp the bulb in the hand; the warmth of the flesh will cause the air within to expand till it drives the water from the hollow stem and escapes in bubbles through the liquid in the tumbler. Such an apparatus is called an "air thermometer." Now remove the hand; as the air cools it tends to resume its former dimensions; but as a portion has escaped, a corresponding quantity of water enters the bulb.

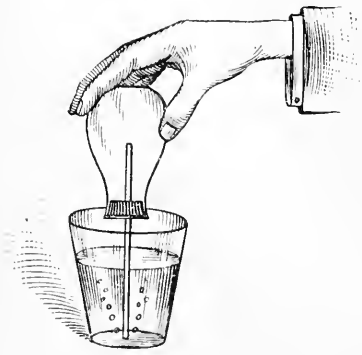

Fig. 48.
Gases expanding when warmed.

Thermometers,—their Construction.—Upon the expansion of liquids by heat depends the action of the ordinary *thermometer*. The word is derived from the Greek

thermos, heat, and *metron*, measure, therefore a measurer of temperature. As commonly constructed, it consists of a bulb of thin glass with which a long hollow stem of fine caliber is continuous; this is shown in figure 49. A quantity of liquid, (usually mercury or alcohol)* fills the bulb and extends some distance into the tube. The stem is hermetically sealed at the top, and the space above the fluid is a vacuum, the air having been removed therefrom before the tube was sealed. A rise of temperature causes the liquid within the bulb to expand; the only direction in which it is free to move is the upward one; the liquid therefore rises. A cooling effect will result in a contraction of the liquid, and a consequent fall of its level within the tube. Such an instrument will reveal the fact of a difference of temperature; but the degree of difference cannot be determined till the thermometer is graduated.

Fig. 49. Thermometer bulb and stem.

The Fahrenheit Scale.—The inventor of the instrument was a German scientist, one Gabriel Fahren-

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*Mercury (quicksilver) is usually employed in thermometers As this liquid freezes, however, at about — 40° F. (i. e. 40 degrees below zero on the Fahrenheit scale) a mercury thermometer is useless for determining temperatures below that point. For low temperatures, thermometers containing alcohol are used. As alcohol boils at about 175° F. such a thermometer is unavailable for measuring temperatures higher than that.

heit, who lived in the early part of the last century. He set his thermometer in ice, and marked upon the tube the level at which the mercury stood: this degree of temperature he properly called the "freezing point." The instrument was then transferred to a bath of boiling water, and the level at which the mercury then stood was marked on the tube, and the temperature was named "boiling point." In a somewhat arbitrary manner, Fahrenheit then divided the space between the marks on the tube into 180 sections; these he called "degrees." Fahrenheit knew that ice was not the coldest thing in existence; by mixing snow or cracked ice and salt he produced a much lower temperature; so in a mixture of this kind he immersed the thermometer, and the level of the mercury was marked and called "zero." the space between that point and the freezing point was divided into 32 degrees. On the Fahrenrenheit scale, (indicated by the abbreviation "F.") therefore, the freezing point is 32° above 0°, and the boiling point is (180° + 32°=) 212° above 0°. With a tube of uniform caliber, the graduations may be carried above and below these points. This scale of thermometric readings, though

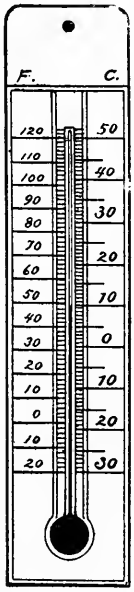

Fig. 50.
Thermometer graduated by the F. and the C. systems.

very arbitrary in its nature, is the one most generally used among English speaking nations; though for scientific and technical purposes another system has been adopted.

The Celsius or Centigrade Scale.—A Swedish scientist named Celsius, proposed to call the freezing point 0°, and the boiling point 100°, the space on the thermometer stem between the points thus indicated being divided into 100 equal parts; and the graduation being continued both above and below these fixed points. The Celsius graduation is sometimes called the centigrade scale; it is indicated by the abbreviation "C." Figure 50 shows a thermometer of simple construction, with scales attached after both the Fahrenheit and the Celsius (or centigrade) systems.*

Relation Between the Two Scales.—The heat needed to raise a quantity of water from the freezing point to the boiling temperature will cause the mercury in a thermometer graduated after the Fahrenheit system to rise from 32° to 212°, or through a space of 180 degrees; and the same heat would raise the mercury in a Celsius thermometer from 0° to 100°, or through a space of 100 degrees. It will be seen then that:

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*Another thermometer scale is that devised by Reaumur, a French philosopher. On the Reaumur scale the freezing point is called 0°, and the boiling point 80.° Therefore 80 Reaumur degrees correspond to 100 Centigrade degrees, and to 180 Fahrenheit degrees; and 80° R. = 100° C., = 212° F., that is, the boiling point of water. In the same way, 0° R. = 0° C. = 32° F., that is, the freezing point.

180 F. degrees correspond to 100 C. degrees.

Then 9 F. " " " 5 C. "

1 F. degree corresponds " $^5/_9$ C. degree.

And 1 C. " " " $^9/_5$ F. "

Now, although as shown above, 180 of the Fahrenheit degrees correspond to 100 of the Celsius degrees, it does not follow that the 180th degree above 0° F. should correspond to the 100th degree above 0° C., because the 0 of the Celsius scale marks the freezing point, while the 0 of the Fahrenheit scale is 32 Fahrenheit degrees below the freezing point. An allowance for this must be made in transforming the readings of one scale into terms of the other. The truth of the following formulæ will be seen without difficulty by the thoughtful student:

$$F. = {}^9/_5\ C. + 32.$$
$$C. = {}^5/_9\ (F.—32).$$

Utility of the Thermometer.—The thermometer is an instrument of great utility, and it certainly deserves a more extended service than is commonly allowed it in domestic operations. We are apt to place too much reliance in the indications of our organs of sense as to temperature, and these indications are often deceptive.*

*The old-time demonstration will illustrate the point. Provide three bowls or basins of medium size; into the middle one put water of ordinary temperature, say about 65 degrees F.; into one of the remaining vessels put some ice water; within the third place water as hot as can be borne without injury when in contact with

Many cheap thermometers are inaccurately graduated; their error, however, seldom exceeds 2°. For domestic purposes, a thermometer possessing the following characteristics will be found most generally useful:

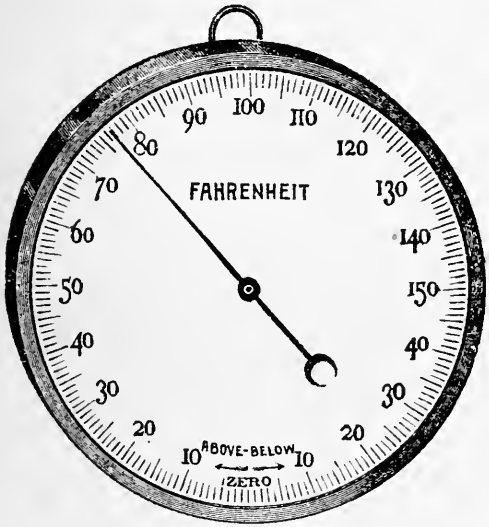

Fig. 51.
Dial-face thermometer.

(1) The graduation markings should be on the glass stem rather than upon an attached scale.

(2) If set in a frame the tube should be readily removable that it may be used when so needed, to determine the temperature of liquids.

(3) The graduations should extend at least from 0° to 212° F.

The Dial-face Thermometer.—Figure 51 is an illustration of a thermometer of recent production now

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the flesh. Now immerse one hand in the hot liquid, the other in the ice water; take notice of the sensations, then plunge both hands into the bowl of water at ordinary temperature. To the hand that came from the hot water this seems unendurably cold; to the hand just taken from the ice water, the contents of the middle bowl seem to be intensely hot. Neither of these sensations indicates the truth.

growing in use. The changes in temperature are indicated by the movements of an indicating finger over a dial face on which are marked in bold figures the degrees. The advantage of such an instrument is that its indications can be read from a considerable distance; whereas, in using the mercurial thermometer the observer must stand very near the instrument; thus influencing the reading by the warmth of his own body. The essential internal parts of the dial-face thermometer are shown in figure 52. A curved bar of metal, (or better, a compound bar of two metals) A B is firmly held at or near one end A. As the bar contracts and expands under the influence of changing temperature, the free end B moves, and this force being communicated through the rod C to the semi-circular piece D, turns the axis F, around which passes a silken thread E. To F as an axle is attached the indicating finger, which moves in front of the graduated face. Such an instrument is graduated to correspond with standard mercurial thermometers.

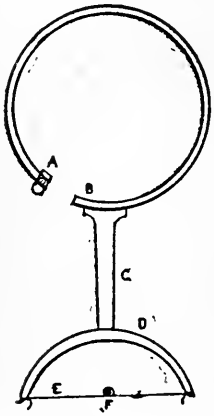

Fig. 52. Essential parts of the dial-face thermometer.

REVIEW.

1. Define heat.
2. What is the general effect of heat on matter?
3. Describe demonstrations of the expansive effect of heat on solids.

4. Give illustrations of the great force exerted by expanding solids.

5. What is the use of a pendulum in a clock?

6. Explain the effect of varying temperature on the regularity of the clock's running.

7. Explain the gridiron compensation pendulum.

8. Explain the mercurial-bob pendulum.

9. Describe experiments showing the expansion of liquids by heat.

10. Illustrate the expansion of gases by heat.

11. What is a thermometer?

12. Describe the mercurial thermometer.

13. Explain its action.

14. Which are the principal scales, according to which thermometers are graduated?

15. How are the fixed points of the scale determined?

16. Show the relation between the Fahrenheit and the Centigrade scales.

17. Deduce formula for transforming the readings of each of these scales into those of the other scale.

CHAPTER 10.

COMMUNICATION OF HEAT; LATENT AND SPECIFIC HEAT.

Conduction of Heat.—If a bar of iron be set with one end in a fire, after a very short time the other end will have become hot. It is plain that in this case the heat must have come from the fire: it must have been communicated along the line of particles from one end of the bar to the other. To be more accurate in expression, we should say the heat has been *conducted* along the iron: in consequence of the property here shown the metal is said to be a *conductor* of heat, and this process of heat-communication is known as *conduction*.

An impressive illustration of this effect may be pro-

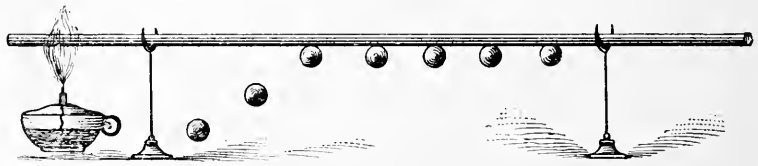

Fig. 53.
Conduction of heat in a bar of metal.

duced as follows:—Provide a thick iron or copper wire, about a foot long (see figure 53), by means of wax attach to the bar at equal distances a number of marbles or small bullets. Insert one end of the bar in a flame: one by one the balls drop as the wax becomes softened, showing by their successive falls the invasion of the particles by the heat.

The Conductometer.—An apparatus designed to demonstrate the relative conductivity of different metals is shown in figure 54, it consists of a metallic box, carrying a number of rods of different substances. The free ends of the rods are first covered with wax; the box is then filled with hot water, and the order in which the wax on each rod liquifies is noted.

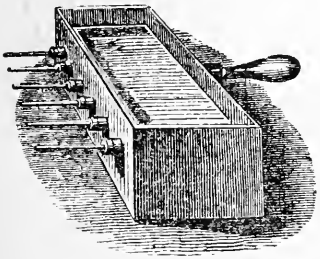

Fig. 54
Conductometer.

Conductivity of some Solids.—The common metals and alloys are arranged in the following order with respect to their conducting powers:

(1) silver;
(2) copper;
(3) gold;
(4) brass;
(5) tin;
(6) iron;
(7) lead;
(8) platinum;
(9) German silver;
(10) bismuth.

To these may be added several common substances other than metals, arranged on the same plan:

(11) marble;
(12) porcelain;
(13) clay;
(14) woods;
(15) fats;
(16) snow;
(17) silk;
(18) charcoal;
(19) cotton;
(20) lampblack;
(21) fur.*

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*Our most efficient fabrics for clothing are poor conductors of heat. A coat of fur or of woven wool, if wrapped about a living being will retain the bodily heat: if wrapped around a block of ice the same garment keeps the ice cold. In the one case the wrapping prevents the escape of heat from the warmer body to the cooler air: in the other it guards the ice against access of warmth.

Convection of Heat in Liquids.—Most liquids are poor conductors of heat. This statement may seem strange when we think of the fact that heat seems to be uniformly distributed throughout liquid masses. Such distribution of heat is effected by other means than by conduction as above described. When liquid particles are heated they become specifically light, and consequently they rise, thus making room for colder particles, which in turn become warmed and rise. The course of the rising currents of warm water and the descending streams of cold may be seen by warming a flask or beaker containing water, to which a small quantity of sawdust or other finely divided, opaque matter has been added; (see figure 55.) Such a mode of diffusing heat by the successive warming of separate particles, is known as *convection*.

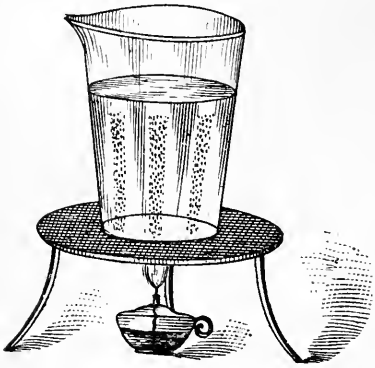

Fig. 55.
Convection of heat in a body of liquid.

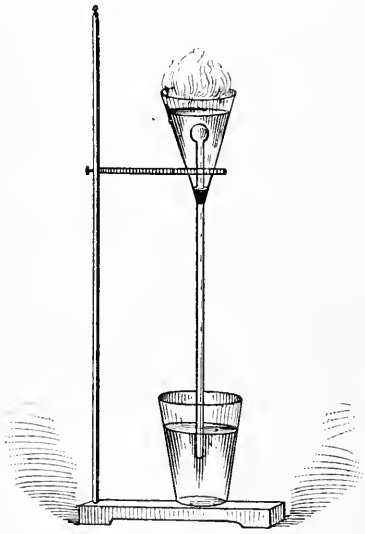

Fig 56.
Inability of liquids to conduct heat in a downward direction.

Poor Conductivity of Water.—If water were a good conductor of heat it would transmit heat as well in a downward as in an upward direction. The inability of the liquid to do this may be thus shown: A funnel (figure 56) with a wide throat is fitted with an "air thermometer" passing through its neck and dipping into a vessel of water below.* Water is poured into the funnel till the thermometer bulb is covered; a little ether is then poured upon the water and ignited. Though the flame be within half an inch of the bulb, so little heat is conducted downward as scarcely to cause an expansion within the bulb.

Radiation of Heat.—There is a third method by which heat is diffused, as may be shown by holding the hand in front of a fire. The flesh soon becomes warmed; not by conduction, for between the hand and the fire there is no material connection, except the air, and air like all gases, possesses but slight conductivity; neither is the hand warmed by convection, for warm convection currents are ascending ones. It is plain that the heat must have penetrated the intervening air; must have traveled from the fire to the flesh. Such mode of heat communication is known as *radiation*, and the heat so transmitted is called radiant heat. Radiant heat passes outward from its source, along straight lines in all directions; the heat rays fall upon objects in their course and warm them, without, however, greatly raising the temperature of the intervening air. Radiant heat

*See figure 48 as an illustration of the air thermometer."

may be transmitted in a vacuum, thus proving its independence of air as a medium of conveyance. The laws of its motion are similar to those of light; it comes to us from the sun associated with light, both traveling at the rate of 185,000 miles per second. The intensity of radiant heat diminishes as the square of the distance from its source increases; therefore a person sitting within two feet of a fire would receive four times as much radiant heat as would fall upon a second person situated four feet from the fire.

HIDDEN HEAT: LATENT AND SPECIFIC.

Nature of Latent Heat.—In speaking of the measurement of heat, we have thus far dealt only with thermometric indications; yet there are many operations in the course of which heat changes are not revealed by the thermometer. Thus a vessel containing ice at the freezing temperature may be exposed to heat, but until the ice has become thoroughly liquified the thermometer would indicate no rise. The energy has not been lost however; it has been expended in separating the ice particles, and in overcoming the cohesion between them so as to produce the liquid state; and this energy will be again freed as heat when the liquid returns to the solid condition.* The heat so escaping thermometric measurement is known as *latent heat.*

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*Though paradoxical, it is true that the freezing process is associated with the liberation of heat, and is therefore in one sense a warming process. In passing from the liquid to the solid

Latent Heat of Melting Ice and of Boiling Water.—The heat thus rendered latent in the melting of ice is about 80 times that required to warm the same amount of water 1° C. Heat is also rendered latent in changing substances from the liquid to the gaseous state. In the boiling of water much heat is absorbed, the steam being no warmer according to the thermometer than was the water at the instant of its vaporization. Experiment shows that to vaporize a given quantity of water at the boiling temperature requires about 537 times as much heat as is needed to raise that same quantity of water through a range of 1° C.

Nature of Specific Heat.—Under all circumstances, water appears comparatively sluggish in responding to the influences of heat. The amount of heat that would raise a pound of water 1° in temperature, would warm 30 lbs. of quicksilver through the same range. We perceive then that different substances possess varying capacities for heat. If to warm a quantity of water through a given range of temperature requires 30 times as much heat as would serve to similarly warm an equal amount of mercury, then in cooling, the water would give out 30 times as much heat as would the mercury. The relative capac-

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state, water gives out all of the heat acquired by it and rendered latent in melting. This principle is often made use of to prevent the freezing of vegetables and fruits during cold weather. Open vessels of water placed in proximity to such perishable articles in a closed room, will liberate sufficient heat to warm the air of the room through a range of several degrees.

ity of substances for holding and retaining heat is known as their *specific heat.*

An instructive demonstration of specific heat may be made thus (figure 57): Procure a number of small balls of equal weight, one each of iron, copper, silver, tin, lead, and bismuth. Heat all to the same temperature by immersing them in a bath of hot oil; then place them on a cake of paraffin or of bees' wax. The iron soon melts its way through the wax; then follow in order the copper, the silver, the lead, and the bismuth. Some of the metals therefore are much better absorbents of heat than are others.

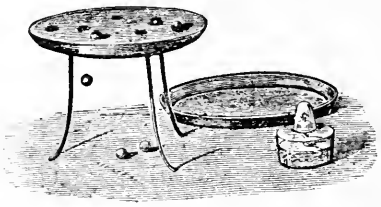

Fig. 57.
Demonstration of specific heat.

Relative Specific Heats.— Considering water as the standard, the specific heat of several common substances may be expressed as follows:

*Water	100
Air	23.75
Oxygen	21.75
Sulphur	20.26
Iron	11.38
Copper	9.52
Silver	5.70
Tin	5.62
Mercury	3.33
Lead	3.14
Bismuth	3.08
Alcohol	5.05
Ether	5.46

*"It is because water is capable of receiving so much heat that it is better adapted than any other substance to quench thirst. A small quantity of it will go much farther in absorbing the feverish

Good Results from the Laws of Latent and Specific Heat.—The beneficial effects resulting from the operation of these laws of latent and specific heat are of the highest order. Suppose for a moment that the principle of latent heat did not exist. As spring time approached, the vast masses of ice and snow of lakes, rivers, and mountains would become warmed to the temperature of 32° F., the melting and freezing point of water; and the least further rise would result in an immediate mighty bursting of the bonds of frost; the ice and snow would become almost instantaneously liquified, and wide-spread destruction would be inevitable. But the All-seeing One has wisely decreed that much heat shall be required to change the physical state of matter; such changes must then of necessity be gradual; and in orderly march, with the precision of prisoners under full control, these frost-bound particles return to their condition of liquid liberty. So, too, the advances of winter are restrained and the severity of the season is tempered by reason of the great amount of latent heat escaping from freezing water. But for the operation of this principle, a fall of temperature only one degree below the freezing point, would result in the instantaneous formation of ice on a stupendous scale. Try to think of the possible results, if as soon as the boil-

heat of the mouth and throat than an equal amount of any other liquid. When swallowed and taken into the stomach, or when poured over the inflamed skin, it is the most grateful and cooling of all substances. For the same reason, a bottle of hot water will keep the feet warm much longer than a hot stone or block."—DR. YOUMANS.

ing point were reached, water was instantly converted into steam. Such a prodigious expansion would be followed by demonstrations of explosive violence, such as man cannot conceive of. Were it not for its high specific capacity for heat, water would respond with alarming readiness to the slightest changes of temperature; and the result could not be other than destructive. But such dire calamities are prevented through the operation of the laws of nature, which are the laws of God. These stupendous forces are under perfect control; the Mighty One holds them in His power.

REVIEW.

1. How would you demonstrate the conduction of heat in a bar of metal?
2. Describe a conductometer.
3. Give the order of conductivity of several common substances.
4. What do you know of liquids as conductors of heat?
5. How would you demonstrate the inability of liquids to conduct heat downward?
6. Explain convection of heat in a liquid.
7. Explain radiation of heat.
8. Define latent heat.
9. In what common processes is heat rendered latent?
10. State the amount of heat rendered latent in the melting of ice.
11. In the vaporization of water.
12. What is specific heat?
13. Describe a demonstration of the difference of specific heat in the case of several substances.

14. Give illustrations of the relative specific heat of different substances.

15. Explain the great benefits resulting from the operation of the laws of latent and specific heat.

CHAPTER 11.

PRODUCTION OF HEAT; FUELS AND FLAME.

Artificial Production of Heat.—The earth is warmed by the heat rays that come to it from the sun. That brilliant orb has been constituted by the Creator as the source of warmth, of light, and of chemical energy for our globe. During the cold season, when we receive less directly these energizing rays, and during the night, when the hemisphere on which we live is turned away from the glowing sun, and for special purposes at other times, it is necessary to provide for the artificial production of heat. The common methods of accomplishing this depend upon the chemical energy of combustion; and when employed for such purposes combustible substances are known as *fuels*.

A Candle.—To aid us in comprehending the chemical processes attending the burning of fuel, let us examine a small flame; that of a candle will answer our purpose well; but first, a word as to the candle itself. A candle consists of a solid cylinder of wax or tallow, or some such easily fusible and combustible material; this is the fuel. In the middle of this cylinder a wick is placed; this serves by its porous nature to convey the melted wax from the little cup at the top of the cylinder to the region of the flame.

Products of Combustion of Candle.—In the burning process a union occurs between the carbon

and the hydrogen of the fuel, and the oxygen of the air. Hydrogen in burning with oxygen produces water; carbon in so combining forms carbon dioxide. Hold over a candle flame a dry, cold goblet (figure 58); water from the flame condenses on the inside of the glass. A similar thing occurs when a cold lamp chimney is placed in position over the freshly lighted wick. Soon, however, goblet and lamp chimney become so warm as not to allow the deposition of water.

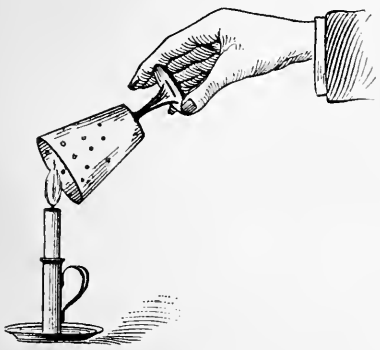

Fig. 58.

Moisture formed by the candle flame condensing on a cold tumbler.

Now arrange an apparatus as shown in figure 59. The gases rising from the burning candle are drawn through the bottle, in which is a quantity of clear lime water. This lime water soon becomes turbid from the formation within it of insoluble lime carbonate. This, it will be remembered from previous experiments, (see page 47) is a proof of the presence of carbon dioxide.

Flame is Burning Gas.—The flame of the candle is due to the combustion of gaseous matters. Fuels containing large quantities of volatile combustible matters burn with large flames; such is the case with resinous woods, soft coals, tar, pitch, oils, and the like; while fuels consisting mostly of fixed carbon, such as charcoal, coke, and anthracite coal, burn with a

steady glow, but with little flame. Indeed, flame may be regarded in all cases as burning gas. To demon-

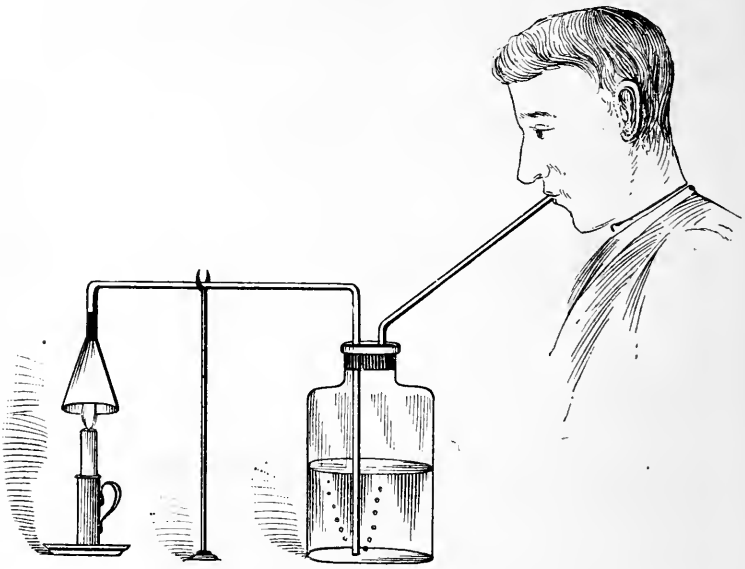

Fig. 59.

Gases rising from a candle flame being drawn through lime water.

strate this fact, let us return once more to our candle. When it is burning brightly, blow it out by a sudden puff; a stream of vapor is now seen rising from the wick; this consists of the volatile part of the wax, which had been carried to the region of the flame, but now that the candle is extinguished it cannot burn, therefore it escapes. Now apply a light to this rising column

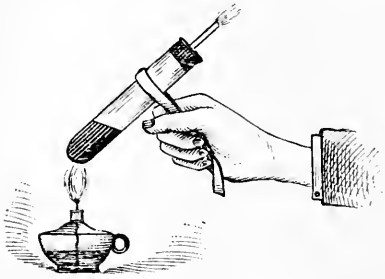

Fig. 60.

Combustible vapors of volatilized wax.

of vapor; the flame runs along the line and re-ignites the wick.

That this combustible vapor is produced through the action of the heat on the wax, may be proved by warming a quantity of wax in a glass tube provided with an escape jet; vapor rises and may be burned as it issues from the jet (figure 60).

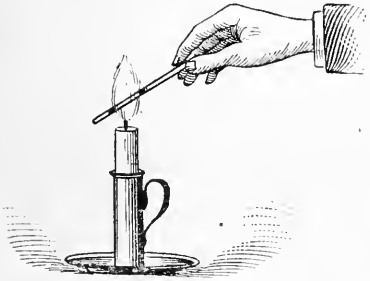

Fig. 61.
Showing that the candle flame is hollow.

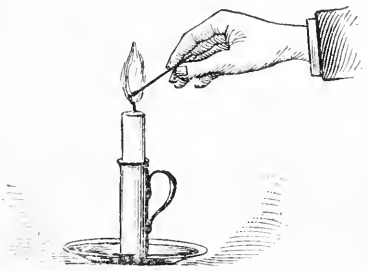

Fig. 62.
Match head in center of flame remaining unburned.

Structure of Flame.—The hollow nature of the flame may be shown by placing a splinter of wood across the flame, as in figure 61. A charring action will occur where the outer shell of flame touches the wood; but between these points the wood is unscorched. By deft action a match head may be introduced into the flame center, and there held unlighted, though the heat may be sufficient to melt the ignition material (see figure 62). A strip of paper may be depressed upon the flame, as in figure 63. On

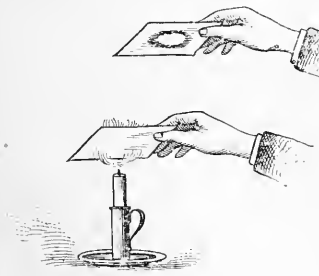

Fig. 63.
Showing that flame is hollow.

being removed a blackened ring, inclosing an unscorched center will be seen.

Fuels.—The processes operating in and about the larger flames may be thus understood from the study of a burning candle. The hydrogen and the carbon of burning wood and coal unite with the oxygen of the air, and in so doing they evolve heat. Fuels are efficient in proportion to the amount of hydrogen and carbon they contain. All solid fuels, however, contain a considerable quantity of incombustible matter; the fixed portions of which remain after the burning in the form of ash.

Moisture in Fuels.—Another cause of the diminution in the heating value of fuels lies in the amount of water contained by them. We all know that green woods, rich in sap, are far less efficient fuels than are dry woods. Water in fuels lowers the percentage of available oxygen and carbon; its presence retards the combustive process, by absorbing much heat as the burning proceeds; and when the boiling temperature is reached, the water is converted into steam, and thus a large amount of heat is rendered latent, and is carried off by the escaping vapor.

Heating Power of Fuels.—The calorific or heating power of fuels depends upon the amount of oxygen with which they unite in the course of combustion. Thus, 1 lb. of hydrogen while burning will combine with 8 lbs. of oxygen; while 1 lb. of carbon unites with $2\,^2/_3$ lbs. of oxygen. Hydrogen in burning produces over three times as much heat as does the same weight of carbon. The practical efficiency of hydrogen as a fuel

is lowered, however, by the fact that the water produced by its combustion absorbs and renders latent a large proportion of the heat. The carbon dioxide resulting from the burning of carbon, having apparently little capacity for heat, and undergoing no change of state, absorbs much less of the heat of combustion. For practical purposes, therefore, the proportion of fixed carbon in fuels largely determines their relative efficiency.

Wood as Fuel is still in extensive use, where it is plentiful. Ordinarily, wood contains a large amount of water.* It is usually allowed to become air-dried before being burned; by this its efficiency is greatly increased. Soft woods burn quickly, and give out a comparatively intense heat in very short time; but they burn out much more rapidly than do hard woods. Common woods may be ranged in the following order with respect to their heating values, the poorer kinds being named first:—white pine, poplar, soft maple, cherry, cedar, elm, hard maple, yellow oak, walnut, beech, apple, scrub oak, white ash, white oak, hickory.

Coal exists in many forms, and of widely varying degrees of efficiency as fuel. There is much evidence

* "Suppose that 100 pounds of wood contain 30 of water, they have then but 70 of true combustive material. When burned, 1 pound of the wood will be expended in raising the temperature of the water to the boiling point, and 6 more in converting it into vapor; making a loss of 7 pounds of real wood or one-tenth of the combustive force. Besides this dead loss of 10 per cent. of fuel the water present is an annoyance by hindering free and rapid combustion."

YOUMANS.

to support the view that mineral coal is but transformed vegetable matter. The remains of many plants are found in mines; the microscope reveals, even in the ash of the hardest coal, a cellular structure similar to that known to exist in plants; a substance very similar to coal has been artificially made through the operation of heat and pressure upon sawdust and other finely divided vegetable matter. Coals are usually classified according to the degree of metamorphism to which they have been subjected, as shown by the varying amounts of volatile matter which they still contain. The chief varieties are lignite, cannel coal, bituminous coal, semi-bituminous coal, and anthracite.*

Lignite, often called *brown coal*, plainly shows the woody structure. It is soft and lusterless, and so different in appearance from the common forms of coal, that at first sight one scarcely considers it as belonging to the same family. A typical sample from Saxony was analyzed by the writer and found to consist of:

Moisture,	8.24 per cent.
Volatile combustible matter,	49.96 "
Fixed carbon,	38.31 "
Ash,	3.45 "

Cannel Coal, which in some places is known as *parrot coal*, is usually grayish black in color, dense and lusterless. When broken it shows a conchoidal or shell shaped fracture. It contains a tolerably large percentage of volatile matter, and is consequently well adapted for the manufacture of gas; in England it is

*See the author's "First Book of Nature," chapter 43.

known as *gas coal*. The name *cannel* is due to a practice still followed in Scotland, of using thin pieces of the coal in place of candles (Scottish pronunciation, cannels). A good sample of cannel coal from Virginia yielded to the author's analysis:

Moisture	0.243	per cent.
Volatile combustible matter	60.818	"
Fixed carbon	35.135	"
Ash	3.882	"

Bituminous Coal contains from 40 to 50 per cent. volatile matter. This constitutes the commonest class of coals. It is a black, lustrous, friable solid, and burns with a large flame. Varieties of this coal that are especially rich in volatile substances are described as *fat bituminous coals.*

The following tables give the composition, according to the author's analyses, of several kinds of bituminous coal as sold in Utah:

	Coal from Weber Co., Utah.	Coal from Rock Springs, Wyo.	Coal from Castle Gate, Utah.	Coal from Pleasant Valley, Utah.	Coal from Sweetwater, Wyo.
Moisture	8.11	7.82	1.21	4.56	8.71
Volatile combustible matter	42.75	43.57	42.81	39.05	33.16
Fixed carbon	46.44	47.28	52.35	54.68	56.88
Ash	2.68	1.30	3.61	1.70	1.24

Coal containing large amounts, say near 50 per cent., of volatile ingredients softens much in burning. Such kinds are popularly called *coking coals.*

Semi-bituminous Coal contains from 15 to 20 per cent. volatile matters. It is richer in hydrogen

than is anthracite, and it contains more fixed carbon than does bituminous coal proper. Owing to its ready inflammability and the comparatively little smoke attending its burning, it is in high favor as a fuel for engines and boiler fires, and is often called *steam coal*.

Anthracite is a hard, brittle, and highly lustrous coal. In structure it is very dense, and in breaking it shows a conchoidal fracture. It may contain upwards of 90 per cent. fixed carbon, leaving therefore small room for volatile ingredients.

A specimen of anthracite coal from Crested Butte, Colorado, gave in the author's analysis the following composition:

Moisture	0.59	per cent.
Volatile combustible matter	6.48	"
Fixed carbon	90.04	"
Ash	2.43	"

In burning, anthracite coal evolves great heat, but produces little or no flame. Coke formed from anthracite differs in appearance but slightly from the coal itself. In different sections of our own country, anthracite is popularly known as *glance coal*, *stove coal*, and *hard coal*; in Ireland it is commonly called *Kilkenny coal*; in Scotland it is called from its flameless burning *blind coal*.

The varieties of coal here named are but the chief or typical kinds. Numerous others are known, differing in degree from the ones mentioned. Besides the natural fuels, certain forms of artificially prepared carbon are also used; the chief of these are charcoal and coke.

Charcoal is produced from wood by distilling off the volatile matters; it remains after the process as a black, brittle solid, containing all the fixed carbon and ash of the wood. Being very porous, charcoal readily absorbs moisture.

The common method of preparing charcoal consists in piling the wood around a central flue; covering the heap with earth, and kindling a fire at the bottom of the flue. Some of the wood is burned and thus produces sufficient heat to distill the volatile matters from the remainder. The energy of the combustion is controlled by regulating the admission of air to the heap. A better method consists in using dome-shaped kilns specially constructed for the purpose. Any method is wasteful if it allows the escape and loss of the volatile ingredients; in the best processes the volatile matters are collected and used. Charcoal has many uses beside those of fuel; some of these will be subsequently referred to.

Coke results from the distillation of coal; it contains therefore all the fixed carbon, and the ash of the coal. It is made in large quantities as a by-product in the preparation of coal gas. Coke is a porous, friable solid, grayish in color, and of medium luster. It is largely used as a fuel in metallurgical operations. Being devoid of volatile ingredients, coke burns with a steady, flameless glow, evolving much heat.

Coal Gas is a very convenient and an efficient artificial fuel. However, the cost of its production and distribution prevents its use as a heating medium becoming general. As furnished by its manufacturers,

coal gas may be regarded as the partly purified volatile matter of coal. Its use is attended by considerable danger, owing to its poisonous properties and the explosive nature of mixtures of gas and air. Coal gas is in more general use as an illuminant, though gas stoves for heating purposes are in frequent service.

Gasoline as Fuel.—Vapor stoves for the burning of volatile oils are now in common use. They depend for efficacy upon the burning of the light vapors of petroleum, such as benzine and gasoline, between which substances, as found in the market, there is very little difference other than that of the prices charged for them.

Tinder-box and Sulphur Matches.—The mode of starting fire is an interesting subject for study. In very early times, it is said our ancestors developed fire by forcibly rubbing together pieces of dry wood ; this method was laborious and its results uncertain, though it is still employed among savage tribes. An advance was made in the use of flint and steel with which to produce a spark, and tinder to be inflamed thereby. In the early part of the present century the *tinder-box* was a household necessity. Sulphur *matches*, consisting of a globule of sulphur on the end of a splinter of dry wood, were used in connection with the tinder, the low igniting point of sulphur making it possible to readily procure a flame from the smoldering tinder.

Phosphorus Matches.—The matches of the present day depend for their inflammability upon the presence of phosphorus. Common matches are made

by dipping the bits of wood in melted sulphur, and afterwards in a paste of phosphorus, potassium nitrate (nitre), and glue. Slight friction inflames the phosphorus, this ignites the sulphur, while the nitre decomposes and furnishes oxygen to aid the combustion. The glue forms a hard coating impermeable to air, so that the phosphorus within the match head is protected from oxidation till by friction the outer layers are worn away. In the crackling or explosive matches, potassium chlorate is used in place of nitre; such matches burn quickly. If a colored match-head be desired, a pigment, usually vermillion, red lead, or Prussian blue, is stirred into the paste.

Safety Matches.—Many serious results have followed the accidental ignition of matches; and as a partial safeguard *safety matches* were invented, though their use has not become general. Safety matches are capped with a mixture of potassium chlorate, antimony sulphide, and glue; they ignite only when rubbed on a prepared plate containing red phosphorus and fine sand or powdered glass. The red or amorphous phosphorus is far less dangerous in use than is the ordinary waxy phosphorus.

REVIEW.

1. What is fuel?
2. Describe the parts of a candle and the changes going on as it burns.
3. Prove that water is a product of ordinary combustion.
4. Show that carbon dioxide is produced by a burning candle.

5. Explain the production of water and carbon dioxide in ordinary combustion.

6. What is flame?

7. Show that the flame of a candle results from the burning of combustible vapors.

8. Describe three demonstrations of the hollow form of flame.

9. Explain the effect of water in fuels.

10. What do you know of wood as a fuel?

11. What evidence have you that coal is probably formed from vegetable matter?

12. Name the principal kinds of coal.

13. What do you know of lignite?

14. Of cannel coal?

15. Of bituminous coal?

16. Of semi-bituminous coal?

17. Of anthracite?

18. How is charcoal produced?

19. What do you know about coke?

20. Discuss coal gas and natural gas as fuels.

21. Explain the operation of the old time tinder-box, flint and steel, in producing fire.

22. Explain the operation of common matches.

23. Of safety matches.

CHAPTER 12.

HOUSE WARMING.

Desirable Temperature for Rooms.—Throughout the temperate and colder regions of the earth, man finds it necessary to employ means for artificially warming his home. In this he aims to secure an indoor temperature which will give comfort and be conducive to health. No exact temperature can be definitely named as being under all circumstances most advantageous. The bodily susceptibilities and requirements of different persons for heat vary considerably; a middle-aged, vigorous man may find no discomfort from cold in a room heated only to 59° or 60° F. while an enfeebled or sickly person may shiver at 70° F. It is evidently advisable, therefore, that a medium temperature should be secured, and the individual peculiarities be met as nearly as possible by suitable amounts of clothing. For the majority of human beings, a house temperature of 62° F. to 68° F. will be found most agreeable and beneficial.

Primitive Fire-places.—Many methods of warming dwellings are known, of these the *open fire-place* properly claims our first attention, by reason of its great antiquity. Among ancient nations the open fire was the only known means of house warming, and the primitive fire-place was a very crude affair. The chimney is a modern invention, being now but

about 600 years old. Before the thirteenth century, dwellings were warmed by a method which is still exemplified in the huts of the Esquimaux—the fire being on the floor near the middle of the room, and the smoke escaping as best it may by the doorway and through a hole in the roof.

Even among the classical Greeks and Romans, but little real advancement was made over this primitive and dirty practice. However they had vessels specially provided as fire-holders; these were known as braziers, and consisted each of a pan mounted on a tripod of convenient height, the whole being ornamented with carving and symbolical devices.*

Early Forms of Open Grates.—The invention of chimneys was soon followed by that of fire-places proper. The first of these consisted of a huge square opening in the wall; but a small part of this space, however, was actually used for the fire, the remainder being occupied by seats along the sides. Count Rumford pointed out some of the many defects of such a structure; he showed that the jambs or side walls, if built so as to directly face each other, that is, at right angles to the back of the fire-place, would simply

* Dr. Youman says of the Roman fire-place: "They (the Greeks and Romans) kept fires in open pans called braziers. Those of the Romans were elegant bronze tripods, supported by carved images with a round dish above for the fire. A small vase below contained perfumes, odorous gums and aromatic spices, which were used to mask the disagreeable odor of the combustive products. The portions of the walls most exposed were painted black, to prevent the visible effects of smoke, and the rooms occupied in winter had plain cornices and no carved work or mouldings, so that the soot might be easily cleared away.

reflect the heat rays back and forth between them; whereas if the walls were placed at a widening angle with the back, according to the laws governing the reflection of rays of force, much of the heat and light would be thrown into the room. He concluded that the best angle at which the jambs could be set was 135° with the back of the hearth.

Essentials of an Efficient Fire-place.—The modern fire-place is by comparison a dwarfish structure; the open space leading into the chimney above the grate is reduced to a minimum, and the grate itself is made to project into the room. In England, the open grate remains still in general use, and some improvements are there being introduced. The following features are considered by many English authorities (notably Parkes and Teale) as essential in good fire-places: The back of the grate should be about one-third as wide as the front; the sides set at the angle of 135°; the sides and back should be of fire-brick; the back should be inclined forward, that the flames may play upon it, the whole fire-place being carried well forward into the room; the chimney throat should be narrowed as much as possible; and the fire-place and chimney should be built in the inner walls of the house, so that the escaping heat may do some good in warming the upper rooms.

Advantages and Disadvantages of Open Grates.—Many people speak in favor of the open grate as a heating device, and others present strong objections to its use. The brilliant glare of the burning fuel, fully exposed to our view, imparts a cheerful

influence; it is in the nature of man to love warmth and light, and therefore he has pleasant preferences for the open grate;—and farther, there are many substantial benefits arising from its use. The heat derived from a clear, open fire is almost entirely radiant heat, the air of the room never becoming burnt or excessively heated, and, farther, the fire does much to promote efficient ventilation. On the other hand, open fire-places are dusty and dirty additions to a room; ashes and soot are sure to escape from them into the apartments; the radiant heat warms chiefly the side of persons and objects that is directed toward the fire, and in the coldest weather, when the efficiency of our heating appliances is taxed the most, this inequality of warmth is found most distressing. In addition, open grates do not secure to the room a uniform temperature; but very inadequate regulators of the combustion, such as dampers and valves, are provided, and the varying intensity of the burning as the fuel in the grate becomes low and is then replenished, will effect rapid changes in the temperature of the room. As regards economy of fuel, nothing can be said in favor of the open hearth; experience has demonstrated that the best grates of modern construction allow fully 70 per cent. of the heat to escape up the chimney, and in poorly constructed grates the proportion of loss may reach even 90 per cent.

Stoves of various forms are now in common use for domestic warming. A stove may be described as a box, usually of metal, so constructed as to favor the combustion of fuel placed within it, and to allow the

ready removal of the gaseous products of the burning. Stoves communicate heat to the room, partly by radiation but mostly by convection. The air in contact

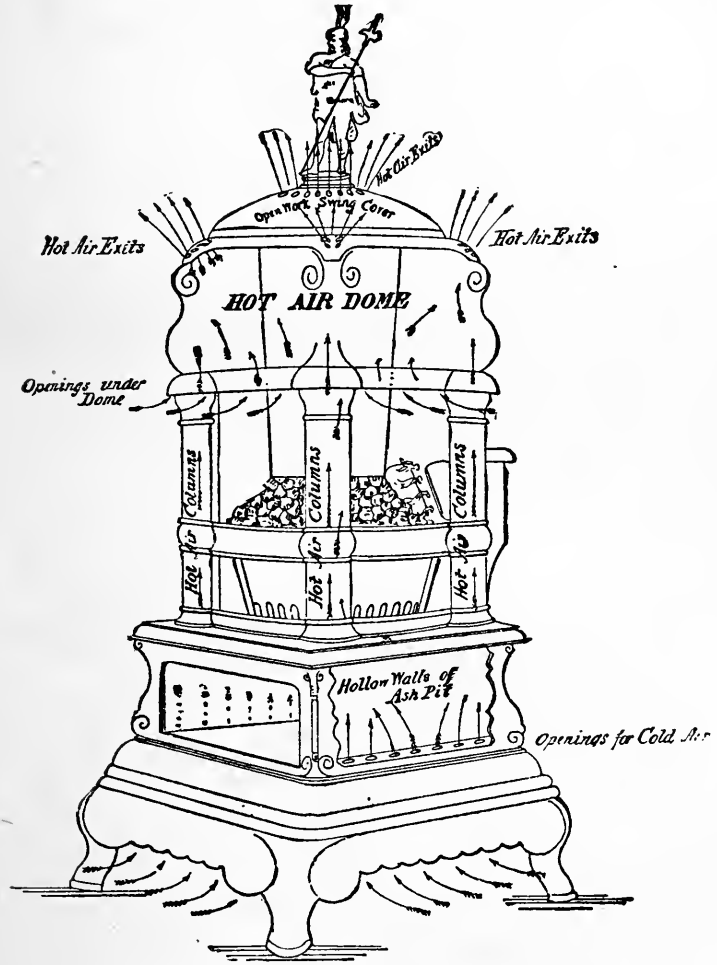

Fig. 64.
Double-case stove.

with the heated surface becomes warm, in consequence of which it rises and gives place to a quantity of

colder air. The air of these rising currents coming in contact with the colder ceiling and walls, contracts and sinks; thus circulating currents are created within the room. The pipe which leads from the stove to the chimney opening imparts much heat to the room; and this effect is materially increased if elbows are placed in the pipe. The reason for this is simple—the cooling of the heated gaseous contents of the pipe can occur only at the surface of the column; such process will be necessarily slow, and much of the heat will be carried to the chimney; whereas if the current be broken up as by means of angles in the pipe, a circulation within the moving column will be caused, and more air will come in contact with the pipe walls, thus favoring the transmission of heat into the room. Figure 64 illustrates the essential parts and action of the double-case stove.

Advantages and Disadvantages of Stoves.—Stoves are of but slight appreciable benefit in room ventilation; indeed, it is said to their discredit that they are of actual detriment, through allowing the escape of injurious gases from the fire. In stoves of poor construction, and in the best of stoves badly managed, this charge is certainly well founded; but good stoves under efficient control are not necessarily as detrimental to health as has been claimed. However, if the iron walls of the stove become too highly heated, poisonous gases, principally carbon monoxide, will escape from the fire into the room. Hot iron, especially if it be cast iron, is readily permeable to the deadly carbon monoxide, as also to other gaseous

products from the fire box. Heated iron surfaces are apt to char the organic impurities of the air in contact therewith, imparting to it a foul smell, and other injurious properties. These ill effects may be prevented in a great measure by using stoves with large radiating surfaces, so that no necessity exists of over-heating any part. The fire-box of heating stoves should be surrounded by fire-brick or other non-conducting material: such a casing would assist in regulating the temperature changes resulting from the varying intensity of the fire. Another decided disadvantage attending the use of stoves lies in the consequent dryness of the atmosphere. As air becomes warmed, its capacity for moisture increases, and the relative humidity of the air is greatly diminished. This may be partially overcome by placing open vessels of water on the stove or about the room. Though the use of stoves is attended by many serious disadvantages, it is safe to say that their demerits have been in some cases over-stated to the raising of a strong popular prejudice against them. Good stoves if large and well supplied with draught-valves and dampers,* may be used in house warming with great success.

Warming the Lower Portions of Rooms.—All the heating arrangements thus far described, tend to render the upper parts of the rooms warmer than the

* The method of placing a damper or regulating valve in the pipe is a bad one; since when such a valve is closed the gaseous products of combustion will surely be thrown into the room. The draught regulators should be so placed as to control the admission of air to the fire, not arranged to check the escape of gases.

floors, which condition is directly opposed to the requirements of health ; cold feet are the precursors of many forms of illness. The methods yet to be referred to promote the distribution of heat at the floor.

Warmed Air is extensively used as a medium in domestic heating. In this system, fresh air from without is carried to the furnaces by means of pipes and there it is raised to the proper temperature ; thence it is carried through distributing pipes to the rooms to be warmed, and then discharged through register apertures in walls and floors. The most serious defect of the warm-air system lies in the fact that the air becomes relatively dry, being in some cases actually scorched, and consequently tainted from the charring of the contained organic matter.

Steam Warming is held in high favor as a means for heating dwelling houses and large buildings. The essential features of the process are these: steam is generated in a properly constructed boiler ; the vapor is conveyed through pipes to the apartments that are to be warmed : there the steam is passed through one or more *radiators* (Fig. 65) consisting of a pipe arranged in many parallel sections. In condensing, the steam imparts its heat to the air of the room. The latent heat of vaporization has been already explained; (see page 125)—It will be remembered, that in passing from the liquid state at the boiling temperature (212° F. or 100° C.) to steam at the same temperature, 537 times as much heat is absorbed as would be required to raise the temperature of the same amount of water

1° C. This latent heat, though not measurable by the thermometer, is retained by the steam; and in the condensation of the latter, the whole amount of heat is again liberated. Thus water may be vaporized in the cellar, and the steam may be made the carrier of heat into the most distant parts of the house. How admirable is the operation of this principle! how cleanly, efficient and economical is this method over that of grates or stoves in rooms, with their inevitable accompaniments of dust and dirt, irregular temperature, uncontrollable draughts, woful waste of energy! The boiler may be situated at any reasonable distance from the rooms to be warmed. If far removed, however, it is necessary to protect the pipes with coatings of non-conducting material, else much heat will be lost on the way. The conducting pipes are usually wrapped with many layers of asbestos fibre; then with hair felt, and outside of this with several thicknesses of stout paper; on this, strips of wood are laid lengthwise and the whole is bound together by wire. The pipe thus wrapped is inclosed in a wooden tube, usually a hollowed log. Such insulation is not

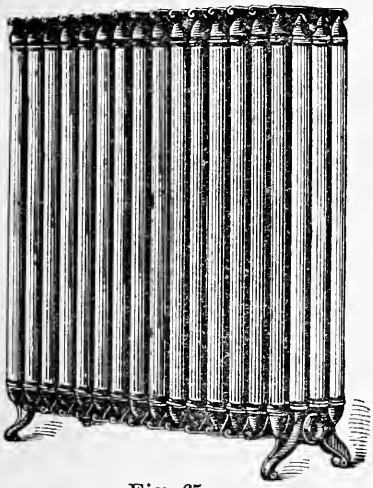

Fig. 65.
Steam radiator.

needed in cases wherein the pipes are not exposed for any great length.

Warm Water Warming.—The warming of houses through the medium of warm water depends for its efficacy upon the high specific heat of water (see page 126), by virtue of which it absorbs for a given rise of temperature a greater amount of heat than does any other liquid, and in cooling through a given range of temperature a correspondingly large amount of heat is given out.

In the *Low Pressure System* of heating by water, the pipes are so connected with the boiler as to allow a complete circulation ; the water returning to the boiler after having traversed the circuit of pipes. From the highest point in the course of the pipes a vent is provided for the escape of steam and heated air. The water in this system can never exceed in temperature the boiling point—212° F., and therefore no scorched or excessively dry state of the air is possible.

The method known as the *High Pressure System* requires the use of very stout pipes without a vent. No boiler being used, the pipes pass directly through the furnace and no escape being provided, the inclosed water becomes heated under pressure ; its temperature may therefore be raised far above the ordinary boiling point ; still, as there is no room for expansion, steam is not produced. In this system, the water is sometimes raised to a temperature above 300° F.

REVIEW.

1. What is your opinion as the most desirable general indoor temperature?
2. State what you know of the antiquity of the open fire place.
3. Describe the Roman fire place.
4. Give reasons for your opinion as to the desirability of open fire places in rooms.
5. State the essential features of a good fire place.
6. How may stoves vitiate the air of rooms?
7. Explain the operation of the double-case stove.
8. State the essential features of a good heating stove.
9. Where should the damper or regulating valve be placed in a stove?
10. Explain the method of heating rooms by warmed air.
11. Explain the process of steam warming.
12. Explain the principle of heating rooms by means of warm water.
13. Explain the low pressure system of water warming.
14. Explain the high pressure system of water warming.

CHAPTER 13.

LIGHT AND LIGHTING.

Light, Natural and Artificial.—During the daytime we depend for light directly upon the rays that come to us from the sun ; this we call *natural light;* throughout the dark hours, we adopt various means for the local production of light; this we call *artificial light.* In reality these terms are misleading; the light of lamp and candle is natural light; it results from the combustion of various animal and vegetable matters, all of which grow under the influence of the sun's energy.

Daylight is free to all; we are only required to provide for its admission to our homes. It is not doled out to us by the pound or the quart; no company's agent calls to read the metre and prepare the bill of our indebtedness. Light, the purest and the best that the physical eyes of man have ever come to know, is showered with a Creator's liberality upon the world. It floods all places that are open to it. Yet how careless we grow as to its distribution and use! Physiologists declare to us that light is as essential as is warmth to the welfare of the body. Our homes then should be well lighted.

Light in Dwellings.—It is true that the delicate organs of sight may be seriously impaired through exposure to light of unusual brilliancy; but the eye

strain induced by deficient illumination, is a far more frequent cause of sight deterioration. The illumination within dwelling rooms should be such as to produce in the eye a feeling of ease and comfort; no strain should be experienced when closely viewing any object within the range of vision. For a person sitting at the table reading or writing, the light should come from above as through a skylight, or from the left and back. In this way the paper or book is well illuminated, and the shadow is thrown away from the right hand.

Luminosity of Flames.—For artificial illumination, the methods most commonly employed depend upon the combustion of certain substances, whereby a luminous flame is produced. An exception to this is seen in the case of the electric light. As has already been stated, flame is due to the combustion of gases; solid fuels may evolve great heat and yet their combustion is flameless. Yet many flames are but slightly luminous; for example, hydrogen burning with a very intense heat emits but a very feeble light. The flame of the common spirit lamp, depending upon the combustion of the vapor of alcohol, is almost entirely non-luminous. The luminosity of flame is due to the incandescence of solid particles which are present with the gas. The most intense artificial lights are produced by the incandescence of solids. Many of the carbon particles in the candle vapor are heated to incandescence, the supply of oxygen is insufficient to burn them with undue rapidity; they therefore shine. In an ordinary flame, (figure 66,) several dis-

tinct parts are discernible; A, a dark, central core, in which region no combustion is possible because of the absence of air; B, a luminous cone; and C, an outer envelope.

The Blowpipe.—The intensity of combustion in an ordinary flame may be greatly increased by means of the mouth blowpipe; such as is used by jewelers, chemists and others. The manner of using the instrument is shown in figure 66. By means of such a pipe,

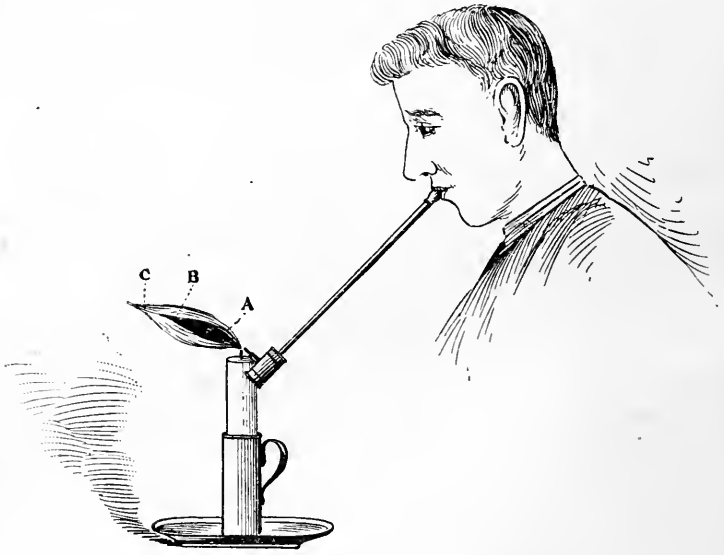

Fig. 66.
Candle flame and mouth blowpipe.

air may be blown into the flame; the flame then becomes a solid one, the combustible materials are more rapidly and more completely burned; few solid particles have time to become incandescent before they are consumed; the result is a bluish, hot, but non-luminous flame.

The Kerosene Lamp.—There was a time when candles were the commonest of household illuminants. The structure of candles and the general nature of their flame have been already noticed. The place of candles in domestic lighting has now been taken by *lamps* in which certain inflammable oils are burned.

A lamp of modern construction (figure 67) consists essentially of a cistern, *b*, for holding oil; supported on a base or pillar, *a*; a wick, *c*, for conveying the fluid to the place of burning; a burner, *e*, for the support of the wick and for the proper distribution of air about it; this is usually provided with a rachet, *d*, by which the wick may be raised or lowered; next a chimney of glass, *f*, to shield the flame from the disturbing effects of draughts. The wicks that were first made were shaped like a solid cylinder; those of later times are flat. Dr. Franklin demonstrated in the case of candles, that two small wicks burned side by side would give greater light than a single wick of double size; this fact is due to the greater surface exposed by the two wicks. The advantage of spreading out the wick fibres thereby enlarging the surface will be readily seen.

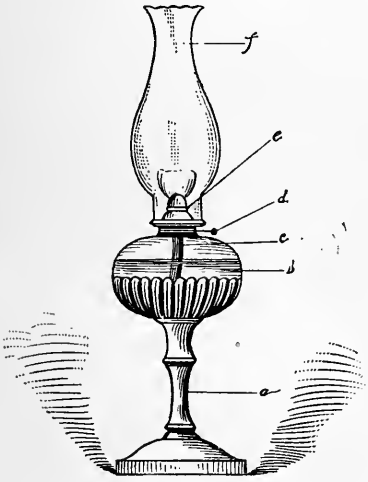

Fig. 67.
Simple form of lamp.

The Argand Lamp.—About 1790, A. D., one

Argand, of Geneva, invented a lamp in which the wick was arranged as a hollow cylinder; this is still in use, and is known as the Argand lamp. The general features of this lamp will be understood from an inspection of figure 68, which shows the complete lamp, and a section of the same. With such a lamp, a large cylindrical flame is produced. By a peculiar construction of the burner, air is introduced into the interior of the flame, so that a more perfect combustion, with a con-

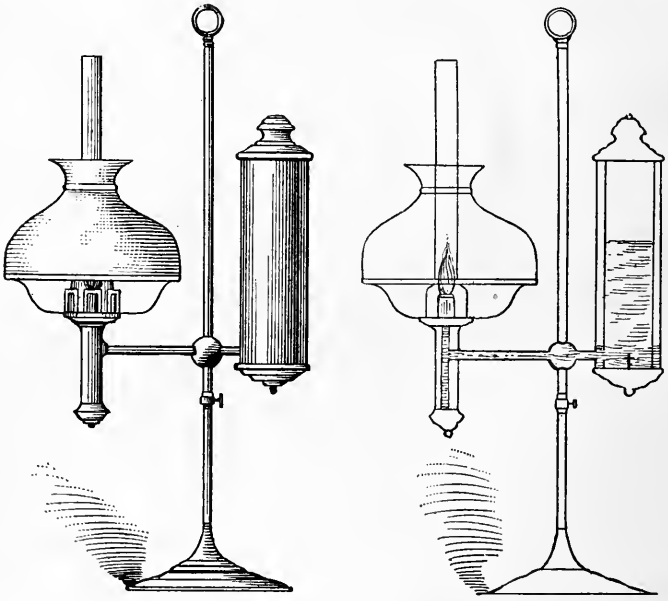

Fig. 68.
Argand lamp and section of same.

sequent increase of light, is the result. The wick may be raised or lowered so that the size of the flame will be proportional to the air current. A valuable improvement on the original Argand lamp was made by Lange, a Frenchman. He proposed a narrowed chimney tube, one having a shoulder in the region of

the flame. The effect of such a chimney is to deflect the outer air current upon the flame, whereby a still greater efficiency is secured. With a lamp of this construction it is possible to burn without difficulty the heavier and poorer oils, because the free supply of air favors a very complete combustion of the carbon, without the production of smoke. The Argand lamp is noted for the steadiness of its flame; it is well adapted to the writing table, and is commonly and appropriaiely called the *Students' Lamp.*

The reservoir of oil is set on the side so as to be safely removed from the heated region of the flame. The reservoir proper is inverted in an outer vessel, and the contained liquid is held in position through pneumatic pressure, and is conveyed to the wick only as fast as used.

Shadows thrown by Lamps.—A serious objection to the use of the Argand lamp for general illumination is based on the shadow thrown by the oil reservoir. The cistern of common, flat-wick lamps is sometimes so shaped as to throw an objectionable shadow. The larger the cistern, the more extensive will be its shadow; yet small oil holders are objectionable, because the level of their liquid contents falls rapidly as the burning proceeds, thus increasing the distance between the oil and the burner, with a consequent diminution of the supply through the wick, and a very marked decrease of light.

Hollow-wick Lamps.—Many forms of hollow wick lamps are now in the market. The appearance and construction of an efficient kind may be understood

from figure 69. The large wick is placed around the hollow cylinder, through which air is carried from below. The base at its place of support is either scalloped or perforated, so as to allow the ready passage of air into the central channel, *a*. A funnel-shaped distributor deflects the inner column of air against the flame. Lamps of this construction afford much light; but they are not well adapted for the writing desk or

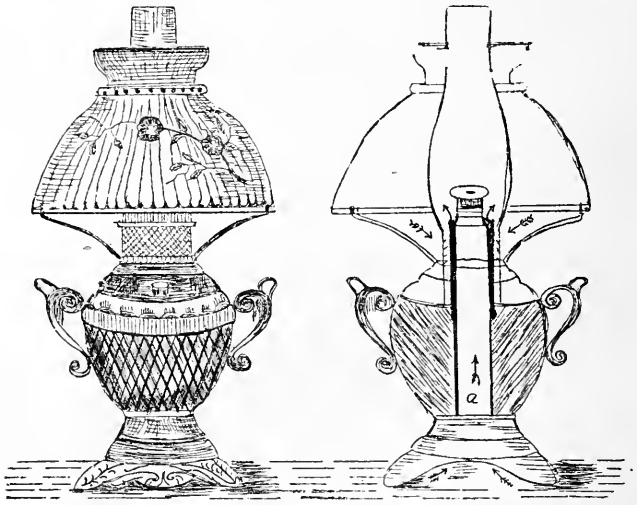

Fig. 69.
Hollow-wick lamps.

reading table, because of the great heat resulting from the large consumption of oil.

Lamp Shades.—It is advisable to surround the lamp chimney with a convenient shade, so as to moderate the intensity of the rays that reach the eye. It is not desirable that light pass in an unbroken line from its source to the eye; its efficiency depends upon the illumination of the objects to be viewed; and ex-

periment has demonstrated that if the eye in viewing an object receives from other sources any rays of light of greater intensity than those reflected from the object itself, the usual impression is weakened, and the organs of sight are unnaturally strained. The value of a shade in deflecting the light downward upon the table will be readily seen. The best shades are made of ground glass or porcelain, and are colored on the inside sky-blue. Artificial light from candles or oil lamps is deficient in certain of the component colors of white light, and the blue shades will partly supply the missing tints. Shades so colored afford less intense but purer illumination.

REVIEW.

1. Why should dwelling houses be well lighted?
2. From which direction should the light come for a person sitting at a desk?
3. Which are the commonest devices for artificial illumination?
4. Describe the parts of an ordinary flame.
5. Describe the mouth blow pipe.
6. Explain the use of the blow pipe in increasing the heat of flames.
7. Describe the parts of an ordinary kerosene lamp.
8. Show the effect of a large wick as compared with a small one.
9. Describe the Argand lamp.
10. Show the value of the peculiar chimney of the Argand lamp.
11. Describe other forms of hollow-wick lamps.
12. What is the use of a lamp shade?
13. State the essential features of a good lamp shade.

CHAPTER 14.

LIGHTING CONTINUED: COMMON ILLUMINANTS.

Illuminating Fluids.—Reference has already been made to candles as sources of light, let us now consider other illuminants. Among the common illuminating fluids, are fish oil, lard oil, colza oil, turpentine, and kerosene. The last named is the common household illuminator. Kerosene is a product of the distillation of petroleum, and, as offered in the market, is of specific gravity* lower than that of water, clear and transparent, the best grades showing a blue tint by reflected light.

Flashing Point and Fire Test.—In burning, the oil is first converted into vapor; this takes fire at

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* The *Specific Gravity* of a substance is the ratio between its weight, and the weight of an equal bulk of some other substance taken as a standard. The common standard for solids and liquids is pure water. When we say that the specific gravity of iron is 7.5, we mean that a piece of iron weighs 7.5 times as much as an equal bulk of water; so we say alcohol has a specific gravity of .8; that is, any volume of alcohol weighs .8 as much as the same volume of pure water. The following list of specific gravities of a few common substances may be of use to the student:

Pure water	1.00	Cork	·24
Alcohol	.8	Pine wood	.66
Turpentine	.87	Ice	.92
Olive oil	92	Marble	2.8
Milk	1.03	Iron	7.5
Mercury	13.6	Lead	11.4
Gold	19.4	Platinum	22.06

a temperature which varies for different kinds of oil; this degree of temperature is known as the *flashing point*; at a somewhat higher temperature the liquid burns continuously, this is known as the *fire test* point. Evidently the use of oil of a low flashing point is attended by great danger from the liability of the mixture of air and vapor within the oil holder to explode. In many parts of the United States and in Europe, there are legal enactments specifying the lowest flashing point that is permitted in oils offered for public sale. The writer has found in the market varying grades of kerosene, of flashing points ranging from 75° F. to 135° F.; and of fire test as low as 110° F.: and as high as 300° F.

Danger from Kerosene Lamps.—The stringency of the laws has done much to restrict the sale of light oils; and it is pleasing to contemplate that accidental explosions in lamps are now infrequent. With the best of oil, however, careless management of the lamp may lead to disastrous results. The common practice of extinguishing the flame by blowing down the chimney often causes ignition in the oil chamber, in which case an explosion is almost inevitable. Allowing a lamp to burn itself out is a dangerous practice; the wick smoulders, and a spark or a glowing ember may reach the oil chamber, and cause a destructive explosion. Some improved forms of lamps are provided with extinguishers; and others have an automatic attachment by which the flame is put out if the lamp be overturned. With the best of contrivances, and under the most favorable conditions, great care

in the management of the lamp is essential to safety.

Coal Gas is used in large towns as an illuminant. It consists of the volatile matter of coal. The production of gas is carried on at the central works, the gas being then distributed through underground mains to the consumers. Good gas is a cleanly, convenient, and an efficient material for illumination; though its presence in the house entails certain dangers demanding constant vigilance on the part of the inmates. An accidental escape of gas into the rooms may form with the air an explosive mixture; and the smallest amount of coal gas in the air of the house, must be regarded as a poisonous addition. The inhalation of any considerable amount of coal gas produces asphyxia and speedy death. It is well for us that the substance possesses a disagreeable odor; for by it we may often recognize the presence of the poison, and we should seek to preserve our sensitiveness to its effects. The gas is consumed at convenient points along the line of the supply pipes, burners of different forms being employed; the commonest burners are the fish-tail, the bat's wing, and the Argand. Gas burners may be provided with an electric attachment, so that the passage of a current from a local battery opens the valve, thus allowing the gas to pass, and ignites it as it issues. With such a contrivance, it is only necessary to press the circuit button, which may be located in any convenient place, and the gas is turned on and lighted. A second push stops the flow of gas, and, of course, extinguishes the light.

Water gas is the name of another illuminant, which

is produced by the decomposition of steam through contact with incandescent carbon. The oxygen from the steam unites with the carbon to form carbon monoxide, while the hydrogen of the steam is freed. Such a mixture of hydrogen and carbon monoxide burns with considerable heat, but with little light; it is necessary therefore to enrich the gas, and this is accomplished by mixing it with the vapors of naphtha, gasoline, or other highly volatile mineral oils.

Vapor Gas.—Another method of using the vapors of light oils as illuminants consists in passing a current of air through such liquids, whereby the air becomes saturated with combustible vapors; in this state it is conveyed through pipes to the place desired and there burned in ordinary gas burners. The apparatus used in the production of this vapor gas is simple and portable; it may be operated in any dwelling house. Care is requisite in using the gas, for dangerous explosions have occurred from the premature lighting of the vapor laden air.

Ventilator Burner.—All the methods of house lighting thus far considered possess the serious defect of contributing largely to the pollution of the atmosphere.* Various forms of ventilator burners have been made; these are designed to carry away through

*Dr. Youmans says :—"A candle (six to the pound) will consume one-third of the oxygen from 10 cubic feet of air per hour, while oil lamps with large burners will change in the same way 70 feet per hour. As the degrees of change in the air correspond with the amount of light evolved, it is plain that gas illumination alters the air most rapidly. A cubic foot of coal gas consumes from 2 to 2 and a half cubic feet of oxygen, and produces 1 to 2

flues the objectionable products of combustion; but all of such contrivances are expensive and inconvenient, and none of them have come into very general use. Vitiation of the atmosphere is inevitable while methods of illumination are directly dependent upon processes of combustion.

Electric Lights.—Such objections are inapplicable in the case of electric lighting. Electric lamps are of two kinds, the arc lamp and the incandescent lamp. In the *arc lamp* (figure 70) the light results from the passage of a strong current through rods of gas carbon set end to end, which are separated at the place of contact. Some carbon particles become volatilized through the great heat caused by the current, these form an incandescent bridge between the separated rods. The arc light is in favor for illuminating streets and large buildings. For illumination on a smaller scale, however, the *incandescent lamp* (figure 71) is preferable. This consists of a globe of glass, sealed, and containing some inert gas such as nitrogen or carbon dioxide, which will not support combustion. A fine, hair-like filament of carbon, B, is placed within the globe, the ends connecting with binding screws, to which the line wires of the electric circuit can be joined. As the illuminating effect is not due to the chemical energy of combustion, it is plain that this method of lighting does not result in vitiation of the

cubic feet of carbonic acid. Thus every cubic foot of gas burned imparts to the atmosphere 1 cubic foot of carbonic acid, and charges 100 cubic feet with 1 per cent. of it making it unfit to breathe. A burner which consumes 4 cubic feet of gas per hour spoils the breathing qualities of 400 cubic feet of air in that time."

air. Incandescent lamps may be operated under water, and in this way aquaria may be beautifully and brilliantly illuminated.

Waste of Energy in Illumination.—Even the best of our methods of artificial illumination are wofully

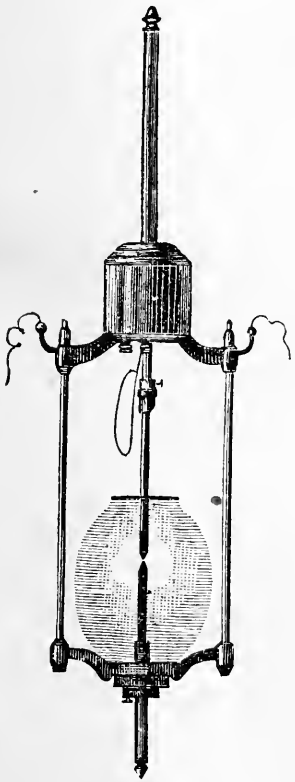

Fig. 70.
Electric arc lamp.

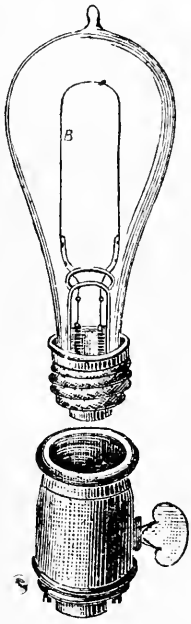

Fig. 71.
Incandescent electric lamp.

wasteful of energy. This is largely due to the fact that much of the energy developed by combustion or through electrical resistance, manifests itself as heat instead of as light. Lamps are intended primarily as

sources of light, and not as heating devices, yet the results of recent experiments by Professor Langley show that 99 per cent. of the energy of candle and lamp flames is lost as far as illuminating effect is concerned; and that in electric lighting, fully 50 per cent. of the total energy fails to appear as light.

The Fire-fly's Light.—Experiments are now in progress to test various methods of producing light with a minimum of loss through heat. Upon this subject considerable interest has of late been stirred by the phenomena attending the fire-fly's glow, and other examples of natural phosphorescence. At present, man is unable to produce light equal in intensity to that of the fire-fly, without an accompanying temperature of nearly 2000° F.; yet the light-giving power of the insect named is exercised without development of sensible heat.

Referring to his experiments on the fire-fly's light, Professor Langley says: "We repeat, that Nature produces this cheapest light at about one four-hundredth part of the cost of the energy which is expended in the candle-flame, and but at an insignificant fraction of the cost of the electric light, which is the most economic light which has yet been devised: and that finally there seems to be no reason why we are forbidden to hope that we may yet discover a method (since such a one certainly exists, and is in use on the small scale), of obtaining an enormously greater result than we now do from our present ordinary means for producing light."

REVIEW.

1. Which are the principal oils used for illumination?
2. What is kerosene?
3. Define "flashing point:" "fire test point."
4. Show the value of high flashing and fire test points in illuminating oil.
5. Discuss coal gas as an illuminant.
6. Water-gas.
7. Vapor gas.
8. What great advantage has electric illumination over the methods which depend upon combustion?
9. Which are the two principal kinds of electric lamps?
10. Describe the arc lamp.
11. The incandescent lamp.
12. Show the great waste of energy in the ordinary methods of household illumination.
13. Name some instances of natural phosphorescence.
14. State what you know of Langley's experiments on the fire-fly's light.

PART II.

WATER.

CHAPTER 15.

WATER—ITS OCCURRENCE.

Water Widely Distributed.—Water is indispensable in many of the processes of life; and in domestic operations it is a prime necessity. Without it, the intricate machinery of civilization would be inactive; and all physical forms of life—the bodies that serve as tenements for deathless spirits—would cease to exist. Indeed, the structure of even the dead things of earth depends largely upon the presence of water. In each of the three great divisions of created things, minerals, plants, and animals, water is present as an essential constituent.

Water in Minerals.—In minerals it forms a very considerable proportion of the total composition, and in many cases gives to the mineral bodies their characteristic color and form. To illustrate this, take a crystal of copper sulphate,—blue vitriol, or blue stone, as it is commonly called: carefully heat it in an iron spoon, or better, in a clean, dry test tube. Very soon steam is seen rising from the crystal; in the tube this vapor condenses on the colder part of the glass, and may there accumulate till it gathers in drops and trickles down the tube in a stream. Now that the water has been expelled, instead of the beautiful, transparent "blue stone," we have left only a grayish powder, entirely undeserving of the popular name. A

drop of water added to this powder will partially revive the azure tint, but the transparency and the symmetrical form have gone forever. The experiment teaches us that the presence of water is essential to the crystalline arrangement of particles within the mass. A transparent piece of alum treated in the same way will evolve large quantities of liquid, and will assume the appearance of a white, opaque powder—the "burnt alum" of the druggists. Chemical analysis has proved that water is ordinarily present in the minerals named below, as specified:

	Per cent. water.
Calcium sulphate (gypsum)	20.9
Copper nitrate	30.1
Copper sulphate (blue vitriol)	36.1
Zinc sulphate (white vitriol)	43.9
Iron sulphate (green vitriol)	45.3
Borax	47.1
Soda alum	47.3
Magnesium sulphate (Epsom salts)	51.2
Sodium sulphate (Glauber salts)	55.9
Sodium carbonate (washing soda)	62.9

Water of Crystallization.—The common designation of water so combined in minerals is "water of crystallization." By mere exposure to dry air, many of the salts named in the table allow some part of the contained water to escape; such process is called *efflorescence*. To observe this, take a few clear crystals of Glauber salts, or of washing soda; put them in an open dish, and set in a warm, dry atmosphere; the substance soon loses its transparency and becomes opaque and friable. This property of solids containing water of crystallization is well known to the

dealers in such substances; grocers and druggists usually store efflorescent salts in tight cases, so as to prevent the escape of the water of crystallization, and a consequent decrease in weight. Washing soda, if exposed in open vessels, may lose over half its weight.

Water Absorbed by Minerals.—Beside the water commonly combined in mineral bodies, and forming an essential constituent of the same, large quantities of the liquid are sometimes absorbed and mechanically retained by minerals. Coal frequently contains even ten per cent. of water. Ores taken from the mines, though seemingly dry, are often so heavily laden with water as to necessitate a drying process preliminary to the furnace treatment.

Water in the Vegetable Kingdom.—In the kingdom of plants water is no less widely distributed nor less essential as an item of their composition. Its presence in vegetable bodies may be easily demonstrated. Place within a dry test tube a chip of wood, a little sawdust, starch, or any other plant product—better select an apparently dry substance, that the illustration may be the more impressive;—now apply heat, taking care not to char or blacken the substance; soon water is evolved as steam, this condenses upon the cold portion of the tube.

Water in Fresh Plant Products.—The following table exhibits the proportion of water in certain fresh vegetable substances, the figures being the average results of numerous analyses by the author and others:

	Per cent. Water.
Pine wood (Utah)	40
Utah apple wood	42
Timothy	70
Meadow grass	72
Lucern	75
Potatoes	75
Red clover	79
White clover	81
Grapes	81
Beets	82
Apricots	83
Apples	84
Carrots	85
Gooseberries	86
Strawberries	87
Cabbage	89
Turnips	91
Cucumbers	97
Water-melons	98

Water in Air-Dried Plant Products.—Through exposure to the air, part of this constituent water will be lost, but even in air-dried vegetable products, very large proportions of water remain, as will be seen from this table; the figures represent average amounts as found by examinations of numerous samples:

	Per cent water
Meadow grass hay	15
Red clover hay	16
Dried pine wood	15
Dried wheat straw	16
Wheat kernel	15
Indian corn	13
Rye kernel	15
Barley	14
Oats	13
Buckwheat	13
Peas	14
Rice	13
Oatmeal	10
Cornmeal	13

Absorption of Water by Plants.—Water is the medium by which the nutritive matters of the soil are carried into the body of the plant. The roots of common plants ramify through the soil in great abundance; the main root giving off many branches, which in turn divide, and subdivide till they become finer than hairs. The root hairs are in close contact with

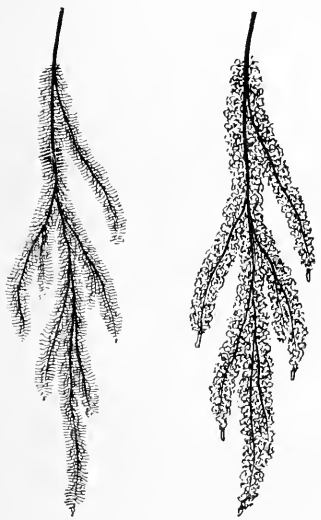

Fig. 72.
Rootlet with roothairs; rootlet with adhering soil.

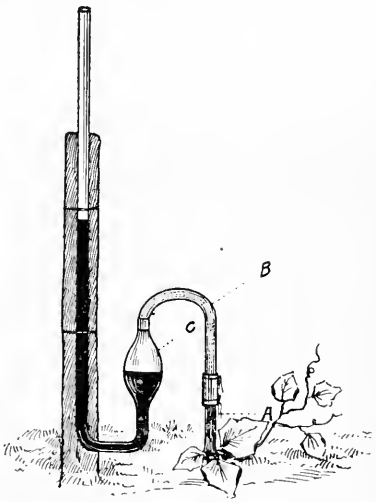

Fig. 73.
Pressure guage attached to a growing plant.

the soil; so close indeed that in many cases it is possible to separate the adherent soil from a root that has been taken from the ground, only by vigorous shaking and thorough washing.

Figure 72 (right sketch) shows the appearance of a wheat rootlet with adhering soil just as it was taken from the earth; and the left sketch exbibits the same

after thorough washing to remove the soil. The numerous root-hairs are distinctly shown. Through the roots large quantities of water are absorbed.

Force of Ascending Sap.—The liquid rises through the vessels of the stem in the form of sap, and in doing so exerts a surprising force. There is a method of forcibly demonstrating this (see figure 73). If a pressure guage consisting of a bent tube B, with mercury in the bulb C, be attached to the stem of a growing plant A cut off near the ground, the rising sap will lift the column of mercury. In an operation of this kind, Dr. Hales found that the pressure exerted during the spring of the year by a young grape vine supported a column of mercury $32\frac{1}{2}$ inches high. This corresponds to a column of water $36\frac{1}{2}$ feet in height or to a pressure of $16\frac{1}{4}$ pounds to the square inch. Hofmeister found that a common stinging nettle similarly tested, supported a column of mercury 14 inches high, due to a pressure of 7 pounds per square inch. The water so absorbed is distributed throughout the entire structure of the plant; many of the solid matters which enter the plant in solution are retained within the vegetable cells; while the water itself escapes through the countless stomata of the leaves.

Water in Animal Bodies.—In the bodies of animals water abounds. A very large proportion of the meats, eggs, and milk we buy is water; this will be seen from the following table:

	Per cent. water.
Fresh mutton contains	71
" beef	73
" veal	75
" pork	76
" fish	80
" fowl	73
" egg	74
" milk	87

The bodies of many of the lower animals consist mainly of water. Agassiz, a scientist of high repute, examined the body of an aurelia (one of the jelly-fishes), from the Atlantic coast of this country; when alive the creature weighed 30 lbs., but when thoroughly dried its body yielded but half an ounce of solid matter,—showing over 99.8 water.

Water in Human Tissues.—It has been proved that the average human body contains water to the extent of from two-thirds to three-fourths of its weight. The proportion of water present in different organs and products of the body will be seen from the following exhibit:

	Per cent. water.
Human teeth	10
" bones	13
" muscles	75
" brain	79
" blood	79 to 80
" bile	88
" milk	88 to 89
" gastric juice	97 to 98
" perspiration	98 to 99
" saliva	99 to 99.5

To supply the body with the requisite amount of water, a man of average size has to imbibe about three and a half pounds of the liquid daily; this would

amount in a year to over 127 gallons. It is, of course, not necessary that this quantity of water be actually drunk, as a very large part of it is supplied from the food.

REVIEW.

1. Show the indispensability of water in many of the processes of life.
2. Prove that water is an essential constituent of many minerals.
3. What is meant by water of crystallization?
4. Give examples of minerals containing large proportions of water.
5. Explain efflorescence.
6. What do you know of the occurrence of water in plants.
7. Give percentages of water in fresh and air-dried plants.
8. How is water absorbed by plants?
9. Describe a demonstration of the pressure exerted by rising sap in plants.
10. State the results of experiments of this kind on certain plants.
11. Give illustrations of the occurrence of water in animal bodies.
12. What do you know of the occurrence of water in the human body?

CHAPTER 16.

WATER—SOME OF ITS USES AND PROPERTIES.

Extensive Uses of Water.—Aside from forming so extensive and important a constituent of minerals, plants, and animals, the uses of water are many and varied. In each of its three physical states, as a liquid (water itself), as a solid (ice), and as vapor (steam), it proves of inestimable service to man.

Water, in the form of running streams furnishes us a continual source of power. Each tiny drop pushes against the wheel, and the current grinds our corn and weaves our cloth; drives our saws and planes, and forces open the vaults in which Nature has stored her wealth of sugar and nectar, of oil and of wine. In its ocean depths, it forms an efficient and easily used road of travel between distant lands; and in both stream and sea it constitutes a home for countless forms of animal life, of value to us for food and ornament.

As **Ice,** it is to us a cheap and an effective protection against decomposition; it stands guard over things most perishable, and successfully repulses the ever eager spirits of decay and destruction. In this form, too, it is held in reserve upon the mountain tops till its presence is most needed on the fields and farms below; and then, bursting away its frozen bands, it

hastens down with a merry babble and a joyous laugh, like the voice of a happy child awakening from peaceful dreams to pleasant play. It carries joy and comfort in its course; the thirsty plants lift up their heads at its approach and smile with thankfulness; the laden beast is refreshed, and the heart of man is gladdened.

As Steam, it drives the wheel of civilization, and has done much to put the stamp of progress upon the present age, and to establish the superiority of God-given mind, over all else upon earth. Its effects have surpassed the achievements of the fabled giants of old, who were said to run a mile at a stride, and to carry houses upon their backs.*

Neutral Properties of Water.—In physical properties, water is the perfection of adaptability to the needs of man. In the most of its characteristics, it is the type of neutrality, being odorless, without color,

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* Water is the common carrier of creation. It dissolves the elements of the soil, and, climbing as sap up through the delicate capillary tubes of the plant, furnishes the leaf with the material of its growth. It flows through the body as blood, floating to every part of the system the life-sustaining oxygen, and the food necessary for repairs, and for building up the various parts of the 'house we live in.' It comes in the clouds as rain, bringing to us the heat of the tropics, and tempering our northern climate, while in spring it floats the ice of our rivers and lakes away to warmer seas to be melted. It washes down the mountain side, levelling its lofty summit, and bearing mineral matter to fertilize the valley beneath. It propels waterwheels, works forges and mills, and thus becomes the grand motive power of the arts and manufactures. It flows to the sea, bearing on its bosom ships conducting the commerce of the world. It passes through the arid sands, and the desert forthwith buds and blossom as the rose. It limits the bounds of fertility, decides the founding of cities, and directs the flow of trade and wealth.

DR. STEELE.

and devoid of taste. High flavors and sweets are not always pleasant to the palate, and the most subtle perfumes are at times sickening and even injurious in their effects. If water possessed positive properties of taste and smell, all our foods, into the composition of which water so largely enters, and in the cookery of which it plays so important a part, would partake of the universal flavor, their qualities would be in all cases modified, and in many instances destroyed thereby.

Water and Heat.—The properties of water under the influence of heat have been dwelt upon in a preceding chapter. Its high specific heat, whereby its temperature changes are modified and retarded, the great amount of heat rendered latent in the fusion of ice and in the formation of steam, with some of the resulting good effects, have also received attention.

Freezing of Water.—In passing from a liquid to a solid form, that is in freezing, water observes a strange and an anomalous behavior. Solidification, or freezing, is the result of cooling, and is usually attended by contraction in bulk. The principle that "heat causes expansion and cold causes contraction," applies to water at certain temperatures only. Above 4° C. or 39.2° F., water expands by heating: below that temperature it expands by cooling; so that a piece of ice is larger than the mass of water from which it was produced. The ice is therefore *specifically* lighter than the water; and as a consequence ice floats in water. If the contraction of water by cold continued to the point of congelation, there would be a

constant rise of warm, and a fall of cold water in the body of the liquid undergoing the freezing process, till the whole would become solid, and in the case of a lake, sea, or ocean, all living things therein would be killed. Farther,—if ice sank as fast as formed in lakes and seas, it would be beyond the reach of the sun's rays, and many tropical summers would be required to thaw the ice of one temperate winter. As it is, however, ice being a poor conductor of heat, the surface layer actually protects the warmer water below from undue cooling.

By reason of the expansion of freezing water, frost is a most valued servant to the farmer, breaking up the hardened clods, and exposing large surfaces of soil to the vivifying action of the air. In an analogous way the rock-masses of the hills are burst asunder, and thus they are prepared for rapid disintegration and speedy conversion into fresh and fertile soils.

Ice Crystals.—Freezing is essentially a crystallizing process, and the microscope will reveal in the snowflake and the ice block a symmetry of parts analogous to that of the stony crystals of earth. The unaided eye perceives the beauties of the hoar frost on pavement and window pane; the glistening spangles suggest flowers, fruit, and leaves; surely the winter is not without its flora. To examine the snow flowers microscopically, choose a cold day when comparatively dry flakes are falling; catch them upon cold pieces of colored glass; do not touch them or breathe upon them; then examine with a low magnifying power. Figure 74 shows a very few of the almost infinite

forms of the crystals of frozen water. Each of them is composed of six main parts or groups of parts, all arranged upon a plan of seemingly perfect symmetry.* The prevailing angle at which the spangles are set with regard to each other is the same in all. Why this constancy? Surely the Great Creator delights in order. Should not we, His children, learn to appreciate the beauties of His wondrous workmanship?

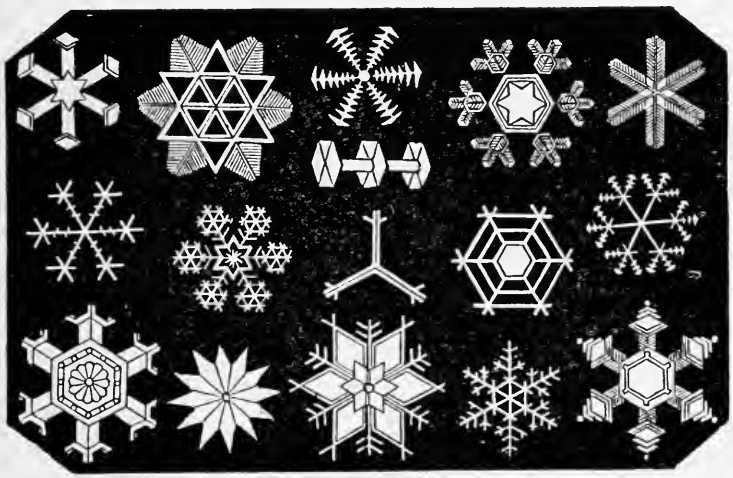

Fig. 74.
Crystals of ice.

Beautifying Effect of Water.—It would be difficult to find a substance that does more than water does in beautifying and diversifying the surface of

*Professor Tyndall describes a certain fall of snow crystals witnessed by him as "a shower of frozen flowers; all of them were six-leaved; some of the leaves threw out lateral ribs like ferns; some were rounded; others arrowy and serrated; but there was no deviation from the six-leaved type."

our earth and its surroundings. The heavenly tints of morn and eve, the varying effects of cloud and mist, the glorious bow, which seals the covenant of the Creator with His children, and which must ever remain an object of our deepest wonder and admiration; —all are largely due to the water drops suspended in the air. The pretty spangles of the hoar frost, the ferns and leaves of the winter window, the stars and flowers of the snow-flake and the ice block, show the operations of the building forces of Nature according to the laws of strict and perfect science.

REVIEW.

1. State the three physical states of water.
2. Show some of the uses of water in the liquid state.
3. Show the uses served by water in the solid state,—as ice.
4. State some of the uses of steam.
5. What you know of the physical properties of water?
6. Describe the exceptional behavior of water in freezing.
7. Show the great benefits resulting to the world from the difference between the specific gravity of water and that of ice.
8. Describe the action of frost in disintegrating rock and soil.
9. Describe the freezing process.
10. What do you know of the crystals of ice and snow?
11. Show some of the effects of water in beautifying the earth and air.

CHAPTER 17.

SOURCES OF WATER.

Primary Sources of Water.—In view of the many and diverse uses of water in the operations of life, it is gratifying to note that Nature has supplied it in unstinted quantity, liberally distributed throughout the world. The water we use is primarily derived from the clouds, through the medium of rain and snow. A part of the water that falls upon the surface of the earth speedily returns to the vaporous condition, and is again ifted into the atmosphere. The inclination of the ground surface and the nature of the soil with respect to its permeability to liquids, will determine what proportion of the remainder will run off in the forms of streams, and what part will sink and percolate through the soil. That portion of the surface water that flows away in streams goes to swell the rivers of the neighborhood; and a part of that which sinks into the soil, serves to supply the roots of growing plants; the rest of the percolating water will probably re-appear at some distant place in the form of springs. In the case of porous soil, this percolation is rapid, so that in some regions it is found necessary to collect the rain water in cisterns as it falls, and store it for general use.

Rain Water is particularly serviceable for many household operations on account of its softness, which

is a result of its freedom from mineral impurities. To procure pure rain-water, the collection should be made in an open space; the water that comes to us from the house pipes is usually almost black from the impurities that it has washed from the roof.

Springs and Artesian Wells.—Much of the water that serves our domestic purposes is derived

Fig. 75.
Hillside spring.

from springs. These are numerous in hilly regions, providing the rainfall is adequate and the soil of proper kind. As the water falls from the clouds upon the hills, a part of it sinks into the soil and descends till it reaches a stratum that is impermeable to the passage of water. Here its downward course is checked, and the water flows along the impermeable layer as along a floor. If this should lead it to the surface of a hill, there the water will issue as a *Hill-*

side Spring (see figure 75). If, however, the course of the floor-stratum should be such as to carry the water below the land surface in the valley, (as illustrated in figure 76) the liquid may continue beneath the earth till it finds or forms a fissure in the earth; from this it escapes as a *Fissure Spring*, or *Main Spring* (B). By boring or driving into the soil, such

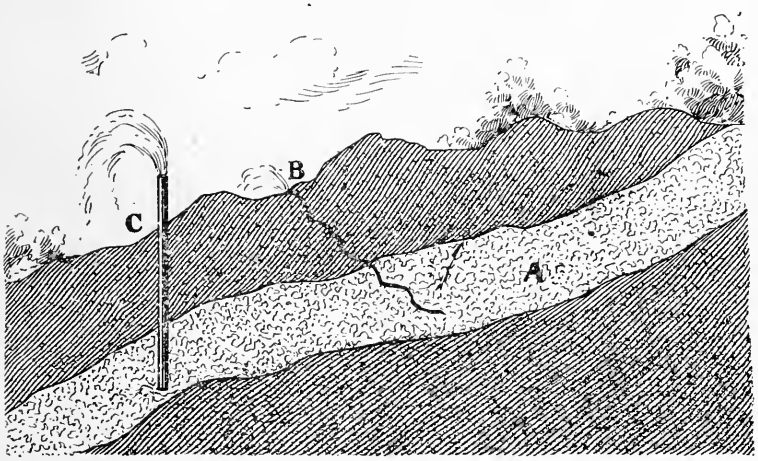

Fig. 76
Fissure spring B, and artesian well C.

subterranean streams may be tapped, the water then rises through the pipe, which may be regarded as an artificial fissure; this constitutes the *Artesian Well* (C).*

*Artesian wells derive their name from the fact that wells of the sort were first made in the province of Artois, France. In some parts of the United States, the name "flowing wells" is often applied to them. In many sections of Utah, wells of this sort are very common; some of them yield per minute from 50 to 100 gallons of water.

Liquids Seek Their Levels.—The force that causes a rise of water through the fissure or pipe will be understood from the following simple observations. If a tube of glass open at both ends be inserted in a vessel of water, the liquid rises within the tube to the level at which it stands in the outer vessel.† Figure 77 represents a central vessel communicating with a number of tubes of different sizes and shapes. If water be poured into such a vessel it will reach the same level in each of the tubes. This fact warrants the oft-used expression, "Liquids will find their level." It is impossible to carry a liquid by its own pressure above the level of its source.

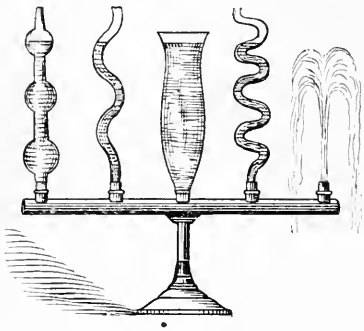

Fig. 77.
Equilibrium of liquids.

By way of further illustration, prepare the apparatus sketched in figure 78. Provide a good-sized funnel, and attach to it a rubber tube. At the other

†If the tube be of small caliber the water will rise to a level higher than that of the liquid in the vessel; this is due to the adhesion between the glass and the water. Such adhesive force when operating in very small tubes is known as *capillary attraction* the term "capillary" being derived from the Latin *capillus*, meaning a hair, and so applied because the phenomenon manifests itself most strongly in small or hair-like tubes. It is by capillary attraction that a piece of bread absorbs milk when dipped in the liquid; that a sponge absorbs water; that a towel dries our flesh. We know how efficient is an un-glazed towel over one in which the pores are closed by an impermeable gloss.

end of the rubber insert a glass pipe. Hold the attached tube so that the free end is level with the funnel-top, and pour water into the funnel; the liquid rises to the same height in the tube. Now lower the tube, so that the opening is below the water level in the funnel: the water now issues as from a fountain, and leaps nearly to the level of its source in the funnel. The friction of the flowing liquid against the tube, the resistance of the air through which it rises, and the force of the descending drops as they strike the rising stream, prevent the exact level being fully reached. So in the case of the fissure spring or the artesian well, the tendency of the escaping stream is to throw itself to the level of its source in the surrounding hills. The right-hand tube in figure 77 illustrates the same phenomenon.

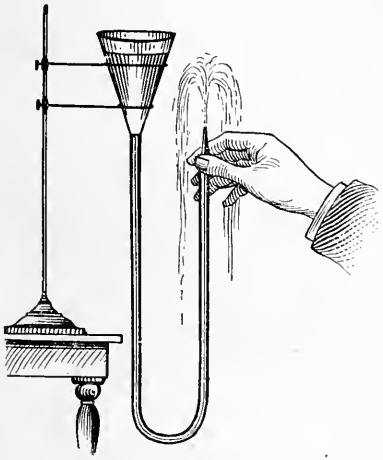

Fig. 78.
Liquid rising to the level of its source.

Intermittent Springs.—There are some springs that discharge water at certain seasons only; these are known as intermittent springs. It is believed that they are due to some such a formation as is shown in figure 79. During a wet season, water would percolate through the soil and gather in the cavern, A; as

soon as it rose above the highest point in the exit passage, B, the water would flow to the opening and there appear as a spring. The flow would continue till the water sank below the entrance to the tube, B; and then would cease till the cavern had again filled to

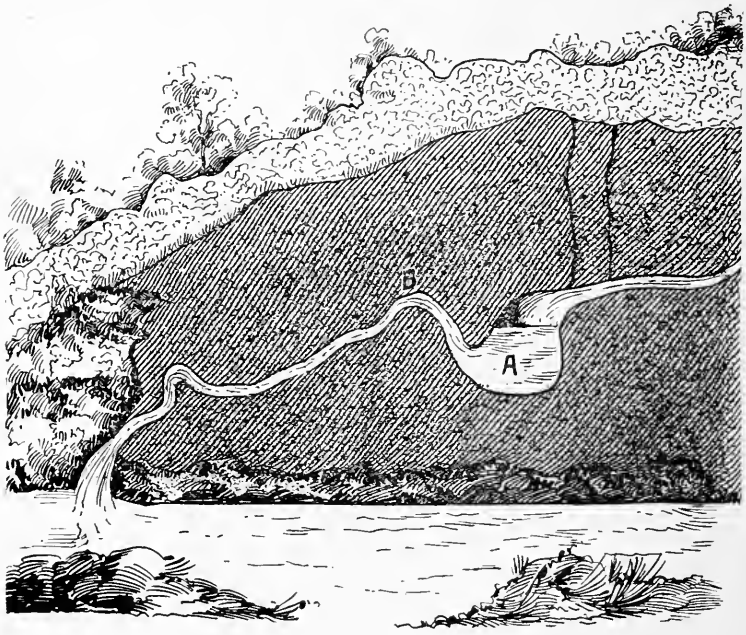

Fig. 79.
Possible cause of intermittent springs.

the former level. This operation is explained by the principle of the siphon, page 35. The action may be well illustrated with the simple apparatus here shown (figure 80). A glass vessel is provided with a bent delivery tube. If water be poured into the receptacle A, till the level of the liquid is above the highest point of the tube B, the water will run through the tube

and the flow will continue till the liquid in the large vessel has sunk below the entrance to the pipe.

Intermittent springs may be due to other conditions than the occurrence of such a cave. In a case similar to that shown in figure 81, during high water season, the level of the subterranean water may reach A, then a flow would occur at S: as the underground water level sinks, however, say to B, the spring would cease action.

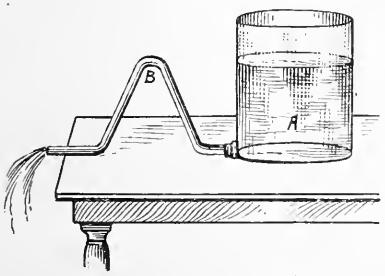

Fig. 80.
Apparatus to illustrate a possible cause of intermittent springs.

Spring Water for Domestic Use. — Potable water from springs is generally well adapted for do-

Fig. 81.
Another cause of intermittent springs.

mestic purposes. The chief cause of objection to its use is its hardness. Water from fissure springs and

artesian wells is generally free from surface filth, the subterranean supply being deeply set. Good spring water is generally clear and well aerated.

River Water.—The water of rivers usually contains much mineral matter, and is, in consequence, hard; it is seldom free from organic impurity. This contamination is the direct consequence of the drainage exercised by rivers upon the land through which they flow. Large quantities of organic filth reach the rivers from manured soils; and in marshy districts the running waters are frequently dark from the peaty matters dissolved from the ground. In the case of large rivers with towns and cities upon their banks, vast quantities of sewage are discharged into the streams, rendering the water entirely unfit for drinking or culinary purposes.

Natural Purification of Running Water.—It is true, certain processes of natural purification are in continual operation, and these greatly mitigate the contaminating effects above referred to. The atmospheric oxygen, which freely dissolves in water, unites with the products of organic decay there present, and thus renders them in time comparatively inert. Running water tends, therefore, to purify itself, but the completeness with which this will be accomplished depends upon the amount and the nature of the dissolved matters, and the proportion of free oxygen present. The extent of this self-purification process is a matter of considerable uncertainty. Some chemists have asserted that a sewage-laden stream will free itself from all impurity in flowing but a few miles, and

others have as strongly denied the possibility of such a thing.* A rapid stream flowing in a stony, precipitous channel, with its waters continually disturbed and broken up, and thus more thoroughly exposed to the atmospheric action, would be far more rapidly purified than would a sluggish stream.

A Local Example may be cited. The Jordan river, flowing past Salt Lake City, received during the summer of 1892 considerable of the city sewage, owing to the inadequate capacity of the pumping apparatus at the sewer station. Analyses conducted by the author on samples of water taken above and below the sewer, showed a great pollution from sewage; and the water of the river did not purify itself to any appreciable degree in a flow of $3\frac{1}{2}$ miles. (See chapter 20.)

Wells.—In country towns, running streams, which have already received attention, and wells, which are now to be considered, are the only common sources of supply. Surface or shallow wells are usually made by digging or boring into the earth till an impermeable layer is reached. Upon this the subterranean water rests, and the well merely taps the supply. At such slight depths the pressure is insufficient to cause the

* In one of the reports of the English Commissioners on River Pollution, it is declared that "the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water; and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidized. It will be safe to infer, however, * * * that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

water to rise of itself as from a deep artesian pipe. The most of such wells, when new, yield fairly good water, hard or soft according to the depth of the shaft and the nature of the surrounding soil; but after a short time, the wells become contaminated through surface drainage. It is evident that the dangers of pollution are greatly diminished in the case of deep wells; the streams that supply these being purified by their percolation through the soil. All surface wells should be frequently cleansed. The openings should be properly protected by curbs and covers, against the accidental entrance of foreign bodies. The best of wells may be fouled through negligence.

REVIEW.

1. What becomes of the water that falls upon the earth from the clouds?
2. For what properties is rain water remarkable?
3. Explain the formation of hillside springs.
4. Of fissure springs.
5. Why does water rise through the pipe of an artesian well?
6. Describe a demonstration of the rising of water to a common level in communicating vessels of different forms and sizes.
7. Explain capillary attraction.
8. Describe a simple illustration of water rising to the level of its source.
9. What is an intermittent spring?
10. Describe a piece of simple apparatus to illustrate a possible cause of intermittent springs.
11. State your opinion as to the cause of intermittent springs.
12. What do you know as to the purity of river water?
13. State what you know of the self-purification of running water.
14. Show the necessity of care in maintaining the cleanliness of surface wells.

CHAPTER 18.

WATER, A SOLVENT FOR SOLIDS; HARDNESS OF WATER.

Solutions of Solids in Liquids.—Water has been called "Nature's universal solvent," and this appellation is justified by the fact that there are few if any substances that can be kept in contact with water without yielding something to its dissolving action. In undergoing solution in water, the particles of a solid body become so separated that the water is uniformly diffused among them. In a solution, the solid particles are so finely divided and so thoroughly incorporated with the liquid that the highest powers of the microscope fail to reveal them. The liquid may be filtered, but the dissolved solid passes through with the menstruum; and in all physical respects the liquid and solid appear as a single substance.

Solvent Action of Water; Saturated Solutions.—The solvent power of water toward different solids is of varying intensity. Thus, a given quantity of water will at ordinary temperatures dissolve five times as much sugar as it will alum. When water has dissolved of any solid the full amount that it is capable of dissolving, the liquid is said to be saturated, and the energy of the dissolving action decreases as the saturation point is approached. In domestic operations the solvent power of water is of very great service. Through it we make our pickling brines, and prepare sweetened and flavored dishes in great

variety; but for it we could not successfully scrub a floor, or even wash our hands.

Effect of Temperature.—The power of water to dissolve solids is greatly influenced by changes of temperature; as a rule heat increases the energy of solution, though to this there are exceptions; thus, hot water will dissolve many times more sugar than will cold water; yet ice water will dissolve twice as much lime as will water at a boiling temperature.

Effect of Finely Dividing the Solids.—In attemping the solution of any solid, the substance should be pulverized as finely as possible, as by such means much greater surface is exposed to the action of the liquid. This may be illustrated by simple means. In an experiment, the writer took a lump of rock salt, an equal weight of ordinary table salt, and the same amount of fine sifted salt. Each of these was placed in a vessel by itself; then an equal quantity of water was added to each; at intervals the vessels were shaken, all being subjected as nearly as possible to the same degree of agitation. The sifted salt was completely dissolve in twenty minutes; the table salt had disappeared in forty-three minutes, by which time the size of the lump had scarcely diminished; and after five hours part of the rock salt was still undissolved.

Effect of Agitation.—The solution of a solid may be much hastened by frequently agitating the mixture, either by shaking or stirring. If the liquid be kept at rest, those portions that immediately surround the solid substance become saturated, and being

thus increased in density they tend to remain at the bottom, so that mixture can take place only by the slow process of diffusion; and the unsaturated liquid above is kept away from the solid body. In an experiment to illustrate this, the author took two equal quantities of alum. These were placed in separate flasks, and to each the same quantity of water was added. The contents of one flask were shaken at intervals; the other was allowed to remain still. In the first vessel the solid was entirely dissolved in three-quarters of an hour, while in the second, part of the alum still remained solid after twenty-two days.

Solids Placed in Upper Part of Liquid.—In preparing any aqueous solution in large quantity, it is well to place the finely divided solid in a basket or a bag of coarse material, and suspend this in the upper part of the liquid. As the water in contact with the solid becomes saturated, its specific gravity is increased, and in consequence it sinks, thus giving place to other liquid particles. As an illustration of the efficiency of this method the following results of experiment are instructive. A weighed quantity of salt was placed in an open vessel, and a measured amount of water was poured upon it. An equal quantity of salt was suspended in a cage of wire gauze, just beneath the surface of a like measure of water in another vessel. In the first, a quantity of solid remained undissolved after three weeks; in the second, all the solid had disappeared from view in forty-seven minutes.

Solids dissolved in Natural Waters.—In consequence of the great solvent energy of water, it is

impossible to find as a natural occurrence a specimen of pure water. It will be profitable to consider briefly the amount and kind of the solid matters in natural waters. The following table shows the amount of total solid matter in certain specimens of water, expressed in grains of solids per gallon of water. The gallon here used is the imperial gallon, equal to 277.27 cubic inches; such a gallon of pure water at the temperature of 62° F. weighs 10 pounds, avordupois, or 70,000 grains.

Source.	Total solids, (grains per gallon.)	Authority.
River Loka, Sweden	0.05	Wells.
Boston, U. S., water works	1.22	Johnston.
Loch Katrine, Scotland	2.3	Wanklyn.
Schuylkill River at Philadephia	4.26	Johnston.
Detroit River, Michigan	5.72	Johnston.
Ohio River at Cincinnatti	6.74	"
Loire at Orleans	9.38	"
Danube, near Vienna	9.87	"
Lake of Geneva	10.64	"
River Rhine at Basel	11.8	Wanklyn.
Thames at London	18.5	"
Average of 12 artesian wells, Provo, Utah	18.6	The Author.
Salt Lake City supply	16.92	"
Spring water, Provo, Utah	23.3	"
Artesian well, near Salt Lake City (west)	43.27	"
Artesian well, near Salt Lake City (south)	23.47	"
Spring, near Salt Lake City (south)	42.68	"
Spring, near Draper, Utah	22.16	"
Spring, Tooele, Utah	24.96	"
Jordan River, below Salt Lake City*	64.15	"

*This large amount of solid matter in the waters of the Jordan river consists in great part of organic impurity. As will be seen by reference to the table of hardness, (on a subsequent page of this chapter) this water is not exceedingly hard.

Source.	Total solids, (grains per gallon.)	Authority.
Formation Springs, Idaho .	27.8	The Author.
Octagon Spring, at Soda Springs, Idaho . .	126.66	"
Well water, Gunnison, Utah .	148.01	"
"Ninety per cent. Spring," at Soda Springs, Idaho .	198.41	"
Warm Springs, Spanish Fork Canyon, Utah . . .	413.72	"
Atlantic Ocean	2,688.00	Wanklyn.
*Salt Lake	11,777.64	The Author.
†Dead Sea	17,064.42	"

The amounts of solid material as expressed above may seem very great, but the actual percentage is small; 10 grains of solids to the imperial gallon represents only .014 of 1 per cent. by weight.

Hardness of Water.—The presence of mineral matter in water may impart to the liquid the property of hardness, which may be concisely defined as the

*The water of the Great Salt Lake is subject to great fluctuations as regards its contents of solid matter, owing to the variations in amount of supply and in the rate of evaporation. In 1849 the lake water, according to Dr. Gale, contained 22.282 per cent. of solids; that time, however, was one of phenomenally low water, and consequently of great concentration. In December, 1885, the author found the water to contain 16.7162 per cent. solids, and in August, 1889, it held 19.5576 per cent. The mean of these two analyses shows 18.1369 per cent., or 11,777.64 grains of solid matter per gallon. During the summer of 1892 the waters of the lake became still farther concentrated. The average of four analyses on different samples collected in September, 1892, showed 14,623.23 grains of dissolved solids per gallon.

†Great discrepancy exists among published accounts of the solid contents of Dead Sea water. Bernan gives 14,025.48 grains per gallon; Captain Lynch collected a sample at a depth of 1110 feet, and found it to contain 18,902 grains per gallon. The amount given above (17,064 grains per gallon) was determined by the author in a sample taken from the Dead Sea in April, 1886, by Dr. J. M. Tanner, of Logan, Utah.

power of curdling soap without the formation of a lather. The minerals most effectual in causing hardness are compounds of calcium and magnesium. Salts of these unite with the fatty acids* of the soap, forming insoluble curdy compounds, and all the lime and magnesium in the water must be so combined before a lather can be produced. A large amount of soap is therefore lost so far as any cleansing effect is concerned. The hardness of water is usually reckoned in terms of this soap destroying power. It has been adopted as a rule among chemists, to consider the soap destroying effect produced by 1 grain of calcium carbonate in a gallon of water as one degree (1°). A water of 10° hardness would contain therefore 10 grains calcium carbonate per gallon, or the equivalent of this in other soap destroying compounds.

Permanent and Temporary Hardness.—Lime carbonate is but slightly soluble in pure water, but dissolves readily in water containing carbon dioxide; this gas is present in most natural waters. By boiling water so charged, the carbon dioxide is expelled, and the lime carbonate being so slightly soluble in the water after boiling, falls as a solid precipitate. Look inside a much-used tea kettle; there will be found a

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*In a chemical sense, soap is to be regarded as a compound of certain alkalies with the acids of fats. The fatty acid in common soap is oleic acid; and ordinary hard soap is chiefly sodium oleate; soft soap is potassium oleate. In contact with hard waters the soap loses its sodium or potassium, these substances being replaced by calcium and magnesium; thus, oleates of calcium and magnesium are produced, which are still soaps, though they are insoluble in water, and therefore valueless for lathering purposes. (See chapter 36, Part IV.)

heavy deposit of lime salts, as thick scale or incrustation. It is plain from this, that by boiling water containing calcium carbonate in solution, the hardness of the liquid may be materially diminished. Hardness that is removable by boiling is called *temporary hardness*. Other compounds of calcium, such as the sulphate (gypsum) and the chloride, as also the compounds of magnesium, impart to the water *permanent hardness*, which is not removed by simply boiling the liquid, because the hardening solids are not thereby precipitated from solution.

Examples of Hardness of Water.—For general household purposes, soft waters are the best, though for many operations a considerable degree of hardness may be tolerated. The following table expresses the hardness of several natural waters:

Source.	Degrees of hardness. Total.	Permanent.	Temporary.	Authority.
London Thames	16.5	—	—	Wanklyn.
Kirby Shore, Westmoreland	25.	—	—	"
Hillside Spring, Provo, Utah	17.	5	12	The Author.
Well Water, Gunnison, Utah	6.5	1.7	4.8	"
Average, 9 artesian wells, Provo, Utah	15.2	5.4	9.8	"
Average, 11 artesian wells, Salt Lake City	18.1	10.7	7.4	"
Salt Lake City supply	13.4	6.9	6.5	"
Artesian well, near Salt Lake City (west)	7.4	1.2	6.2	"
Artesian well near Salt Lake City (south)	17.8	7.1	10.7	"
Spring near Salt Lake City (south)	14.4	10.3	4.1	"
Spring near Draper, Utah	13.1	6.1	7.0	"
Spring, Tooele, Utah	18.5	8.7	9.8	"
Jordan river, below Salt Lake City	16.5	10.8	5.7	"

It is to be remembered that the hardness of water depends largely upon the kind as well as upon the amount of solid matter present. The water from Gunnison, Utah, is named in the table on page 201 as containing 148.01 grains of solid matter to the gallon; yet this is a relatively soft water, as is seen from the table on page 203, which shows for it a total hardness of but 6.5°, and of this 4.8° may be removed by boiling, leaving a permanent hardness of but 1.7°. The solid contents of this water, however, are mostly compounds of the alkalies. The water here referred to is remarkable in many ways; its specific gravity is high, and though it is constantly used as a potable water, its taste is tolerable only to those who have become accustomed to it.

Supposed Physiological Effect of Hard Water.—The continued use of water that is highly impregnated with salts of lime and magnesia is supposed to be a cause of *goitre* or *big neck*. This disorder is an enlargement of the thyroid gland in the neck.* From its prevalence in the limestone regions of Derbyshire, England, it is popularly called "Derbyshire neck." Most recent investigations lead to the belief that the potency of hard waters in producing this disorder has been over estimated. Contaminated

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*Johnston reported that in a jail at Durham, England, all the prisoners suffered from neck swelling. An examination of the water there used showed that it contained 77 grains of solids per gallon, mostly compounds of magnesia and lime. The use of the water was then discontinued, a purer kind being substituted, containing but 18 grains of solid matter per gallon. The goitrous disorder immediately subsided.

water may favor the disease, but that the use of such water is the sole cause can scarcely be credited in the light of demonstrated facts.

REVIEW.

1. Explain the solvent power of water.
2. What is meant by a saturated solution?
3. Show the effect of temperature on the rapidity of solution.
4. Show the effect of finely pulverizing the substance to be dissolved.
5. Show the effect of agitating a liquid in which solution is going on.
6. Why is it best, in preparing a solution of a solid in a liquid, to keep the solid near the surface of the liquid?
7. What condition of natural waters results from this universal solvent power of water?
8. Give examples of the amounts of solid matter in different waters, local and foreign.
9. What do you know of the variation of solid contents in the water of the Great Salt Lake?
10. What is hardness of water?
11. How is the hardness of water determined?
12. How is hardness of water measured?
13. Explain total hardness, permanent hardness, temporary hardness.
14. State what you know of the effect of hard waters on the health of the persons using such.
15. What is goitre?

CHAPTER 19.

WATER,—A SOLVENT FOR GASES.

Air in Water.—The solvent power of water is not confined to its action on solids; gases also may be dissolved in large quantities. The commonest gaseous admixtures in ordinary waters are the constituents of air. Much good results from such solution of air in water; upon the atmospheric gases so held, fishes and other aquatic animals depend for respiration. It is a popular mistake that only land-animals breathe air: without this medium of respiration the tiniest creature of the sea would die. A living fish placed in non-aerated water quickly expires; and the same result follows if the fish be kept in an inadequate amount of water, without renewal; the fish then dies from suffocation caused by its own respiratory products, just as a man shut in a closed room from which the gaseous emanations of his body cannot escape, will be poisoned by his own breath. A strong example of our subject is found in the growth of the tiny coral animals. These belong to the polyp family, and are very small and simple in bodily structure. They possess the power of extracting the calcareous matter from the sea water, and of forming from the same a hard, external skeleton, analogous in composition and use to the shells of mollusks, such as oysters and snails. Corals usually congregate in great numbers, the accumulations of their external

skeletons forming coral reefs. Such reefs are found only in places that are freely exposed to the action of the waves: the little polyps seem to delight in the breaking of the surf, and the whirl of agitated waters. Farther,—they are never found living at a great depth; a hundred feet seems to be their limit. These peculiarities seem to be due to the animals' need for air. In still water, or at a great depth, the coral polyps would be deprived of air, in consequence of which they could not survive; but the agitation of the surface water entangles air sufficient for their use.

Proportions of Atmospheric Gases in Water.—It is remarkable that the atmospheric gases do not dissolve in the proportion in which they exist in the air. In pure air there will be found about 20.9 per cent. of oxygen, and 79.1 per cent. of nitrogen; the other constituents need not be considered in this connection (see page 38). Water that has been fully aerated, however, contains the atmospheric gases in the proportion of 32 per cent. oxygen and 68 per cent. nitrogen. This increased amount of oxygen is of great benefit to aquatic animals, the nitrogen, in respiration serving merely as a dilutent.* To drinking water, the dissolved air imparts a pleasing and somewhat pungent taste. This fact may be realized by

*It has been discovered by Dr. Hayes, "that the water of the ocean contains more oxygen near its surface than at a depth of one or two hundred feet. This fact has probably some connection with the comparative scarcity of animal life at great depths. When water is in contact with an atmosphere of mixed gases, it dissolves of each a quantity precisely equal to that which it would have dissolved if in contact with an atmosphere of this gas alone." WELLS.

anyone who, for contrast, will drink for a time water from which the air has been expelled by boiling.

Solvent Power Affected by Temperature.—Inasmuch as heating water serves to expel its dissolved gases, it is plain that a rise of temperature will diminish the solvent power of the liquid for gases: this view is substantiated by the following facts: Experiment has shown that water at 78° C. is able to hold in solution 586 times its own volume of dried *ammonia gas*; at 59° C. the water can hold 727 volumes; and at 32° C. it may contain 1050 volumes of the gas. A solution of ammonia gas in water is sold as "aqua ammonia," or water ammonia (the common hartshorn of the shops). By warming such, large volumes of the gas will be given off.

The ill-smelling gas, *hydrogen-sulphide*, is soluble in water; indeed the waters of so-called sulphur springs are usually natural solutions of hydrogen sulphide. The influence of temperature upon the solvent power of water for this gas, is illustrated by the following facts: At 78° C. one volume of water dissolves 2.66 volumes of hydrogen sulphide; at 59° C. water dissolves 3.23 times its own volume of the gas: at 32° C. it may hold 4.37 volumes.

Another gaseous substance commonly found in natural waters is *carbon dioxide*. At 14° C. water can hold in solution its own volume of this gas: at 0° C. it may contain 1.8 volumes.

Solvent Power Affected by Pressure.—The pressure to which liquids are subjected greatly affects their power of solution for gases. Thus in the case of

carbon dioxide, under a pressure of one atmosphere (15 lbs. to the square inch), at 14° C. water dissolves its own volume of the gas; under a pressure of two atmospheres, (30 lbs. to the square inch) the temperature being unchanged, two volumes may be absorbed, and so on; within certain limits the solvent power is directly proportional to the pressure.

Soda Water.—An aqueous solution of carbon dioxide constitutes the so-called soda water. By the action of some mineral acid (usually sulphuric acid) on sodium bicarbonate, chalk, or marble dust, carbon dioxide is generated in great quantity; the gas is conducted into a stout closed vessel containing water; as the gas accumulates, the pressure increases; and at the same time the water being kept violently agitated, the gas passes into solution. It will be held captive by the water, however, only as long as the pressure continues; as soon as the liquid is drawn from the holder, the gas escapes giving the effervescent and pungent qualities which are sought.*

* The question of the wholesomeness of soda water has excited some general interest. The presence of small quantities of carbonated water in the stomach seems to produce pleasing and exhilarating effects; and if the preparation be pure, it is difficult to see what harm is likely to result from its moderate use. Some soda-water makers are not careful to use pure water; and are indifferent to the cleanliness of their apparatus. It is possible too, that metallic compounds may result from combinations with the material of the holders and pipes. The admixture of flavoring syrups is objectionable for the reason that the purity of such preparations cannot be relied on, and the coloring matters used to impart the deceptive tints to strawberry, raspberry, blackberry, and other syrups, are frequently of a deleterious kind; and farther, the habitual taking into the system of large quantities of saccharine material is certainly injurious to health.

There are many natural occurrences of carbonated waters: to such class belong the springs of Saratoga, New York, and Seltzer, Germany; as also many local springs. (See chapter 23.) From such springs are taken the so-called natural soda waters, "Seltzer," "Vichy," "Appolinaris," and "Congress."

Injurious Gases Absorbed by Water.—The fact of the readiness with which gases dissolve in water, should restrain us from using for drinking purposes, water that has stood long in open vessels. Water that has been exposed, even for an hour or two, to the air of a closed room, will be found to be charged with the gases of the apartment; and these may be of the most deleterious kind. In the treatment of the sick, precautions are necessary that the patients drink not of any liquids that have been long exposed to the air of the room.

REVIEW.

1. Prove that air exists in water in a state of solution.
2. Of what use is the air dissolved in water?
3. Explain some of the conditions under which coral polyps grow.
4. What do you know of the proportion in which the most abundant atmospheric gases dissolve in water?
5. Explain the effect of a varying temperature on the solvent power of liquids for gases.
6. Illustrate the power of water at different temperatures to dissolve ammonia gas.
7. Hydrogen-sulphide.
8. Carbon dioxide.

9. Explain the effect of pressure on the solvent powers of liquids for gases.

10. How is the so-called soda water produced?

11. What is your opinion as to the wholesomeness of "soda water?"

12. Show the danger attending the drinking of liquids that have been exposed to impure air.

CHAPTER 20.

ORGANIC IMPURITIES IN WATER.

Organic Impurities Deleterious.—The impurities most to be feared in water that is used for domestic purposes are of an organic nature,—that is, they are products of vegetable and animal decay. An average amount of mineral impurities need not render water at all unfit for use. A water containing less than 15 grains of calcium salts to the gallon is usually considered good; and 20 grains of such solids to the gallon is not an unusual amount; but a very small amount of organic impurity may render the water unsafe for drinking purposes.

Nitrogenous Impurities in Water.—Organic matters containing nitrogen are most deleterious. It is common with chemists to determine this organic impurity in the form of ammonia, it being possible to convert such nitrogenous matters into ammonia, and to determine the amount present with fair accurary. The ammonia present in waters as a result of decay that has already taken place is determined as *free ammonia*; the rest of the nitrogenous organic matter, which may be decomposed and converted into ammonia by the analytical process, is called *albuminoid ammonia*. Regarding the amounts of these matters allowable in drinking water according to the established standard of safety, Mr. Wanklyn of England, a generally rec-

ognized authority upon this subject, has said: "I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with 0.05 parts of albuminoid ammonia per million. * * * Albuminoid ammonia above 0.10 per million begins to be a very suspicious sign, and over 0.15 ought to condemn a water absolutely."

Below are exhibited the results of some analyses of natural waters:

	Parts per million.		
Source.	Free ammonia.	Albuminoid ammonia.	Authority.
Town water, Manchester, England	.01	.06	J. A. Wanklyn.
Glasgow, Scotland, Loch Katrine	.00	.08	"
London Thames, at high tide	1.02	.59	"
Emigration Canyon stream, Salt Lake valley	.046	.045	J. T. Kingsbury.
Red Butte Canyon stream	.023	.120	"
Parley's Canyon stream	.010	.060	"
Average 10 artesian wells, Provo City, Utah	2.11	.18	The Author.
Average 16 surface wells, Provo City, Utah	.125	.284	"
In-doors pump, Provo City, Utah	0.73	5.40	"
Artesian well, Spanish Fork, Utah	.72	5.18	"
Average 13 artesian wells, Salt Lake City, Utah	.669	.22	"
Surface well, Salt Lake City	3.28	.34	"
City water mains, Salt Lake City	.13	.052	"
Artesian well, (B) near Salt Lake City (west)*	6.4	.076	"
Artesian well (C) near Salt Lake City (west)	0.74	.004	"

Source.	Parts per million. Free ammonia.	Albuminoid ammonia.	Authority.
Artesian well near Salt Lake City (south)	7.051	.045	The Author.
Spring near Salt Lake City (south)	0.084	.017	"
Spring, near Draper, Utah	0.211	.171	"
Spring, Tooele, Utah	1.96	2.65	"

Chlorine in Water.—Associated with organic impurity of the kind described, water may contain large quantities of chlorine, usually combined with sodium as common salt, or with other alkaline metals as chlorides. These compounds may result from the presence of sewage filth or drainage from cess-pools; though the discovery of chlorine in water, unaccompanied by organic impurity, is not of such serious import.

The following table will convey an idea of the varying amounts of chlorine in different waters. The

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*It will be observed that many of the artesian waters of which analytical results are given in the text, show excessive amounts of nitrogenous impurity. Such contamination, however, is far less dangerous than it would be if occurring in surface water, for, as stated, (page 216) it is not the dissolved organic matter itself that constitutes the source of danger in waters so polluted, but the occurrence of living organisms and germs of disease which are nourished by the organic filth. Waters springing from deep sources are less likely to be infested with such organisms; and during the prevalence of communicable diseases in any place, I would rather drink artesian water, though comparatively rich in dissolved organic matter, than surface water of greater chemical purity, but which had been exposed to infection from surface filth. Though chemical analyses are invaluable in demonstrating the fitness or the unfitness of water for domestic use, such analyses do not tell the whole story.

specifications are given in grains per imperial gallon of 70,000 grains:

Source.	Chlorine. Grains per gallon.	Authority.
Bala Lake, Wales	0.7	Wanklyn.
Thames at London	1.2	"
Average 22 surface wells, Provo City, Utah	1.22	The Author.
Average 8 artesian wells, Provo City, Utah	2.029	"
Average 8 artesian wells, Salt Lake City, Utah	3.688	"
Artesian well (B) near Salt Lake City (west)	1.092	"
Artesian well (C) near Salt Lake City (west)	.435	"
Artesian well near Salt Lake City (south)	.205	"
Spring near Salt Lake City (south)	.629	"
Spring near Draper, Utah	.239	"
Spring, Tooele, Utah	.205	"
Jordan river, Salt Lake City, 150 yards above sewer	1.400	"
Jordan river, Salt Lake City, 150 yards below sewer	1.598*	"
Surface spring, Provo City	.977	"
Artesian well, Spanish Fork, Utah	.992	"
Salt Lake City supply	.87	"

*The Jordan river water just above the Salt Lake City sewer shows 1.4 grains per gallon of chlorine; below the sewer the water holds 1.598 grains per gallon. The increase, .198 grain per gallon must have been derived almost wholly from the effluent sewage; and this amount represents more real danger to the users of the water than does the large amount contained in the water above the sewer: for all the natural waters of the Salt Lake valley are rich in dissolved chlorine, mainly from the common salt and other alkaline chlorides washed from the soil. Chlorine in water, known to be derived from foul sources, threatens danger through the probable association of disease germs.

Real Danger from Organic Impurity.—The presence of small amounts of organic matter would not of itself prove a source of injury to health. The danger lies in the fact that living organisms flourish in water so contaminated, and these may be of an injurious type, since many forms of contagious disease have been proved to be associated with the existence of such organisms within the system. The germs of cholera, small-pox, and many forms of fevers, thrive in water that is organically impure. Dr. Cyrus Edson, the well known sanitary chemist of New York, has declared his belief that ninety-nine per cent. of cholera cases are propagated through the medium of drinking water. The reports of the sanitary officials in India show a close relationship between the epidemic outbursts of cholera, to which that country has been frequently subject, and the use of polluted drinking water. Enteric or typhoid fever is more frequently spread by the use of contaminated water than in any other way.*

Dysenteric Affections from Impure Water.—Dysenteric and diarrhœal affections are in many cases directly traceable to polluted water. The sample named "In-doors pump, Provo City, Utah," in table

* In referring to typhoid fever as a result of the use of water contaminated with filth, Drs. Huxley and Youmans say: "The instances of its originating in this way are too numerous, and have been too clearly traced to admit of a doubt of the fact; nor does mere dilution of the poison remove the danger as the following will show: A recent outbreak in an English town was traced to the milk with which numerous families were served, and it was conclusively proved that the milk was poisoned by being stored in cans that had been washed with water contaminated with sewage from an imperfect drain."

on page 213, was taken from a well, provided with a curb and a drainage pipe. The water was used in a large boarding house, and the fact was reported that severe dysentery was common among the inmates. An examination of the well was made, and the drain-pipe was found to be completely choked, so that the foul wastes made their way back to the well, and this repulsive mixture was drunk. The pipe was cleared, the well thoroughly cleansed, and the derangements in the health of the inmates straightway disappeared.

Diarrhœa Caused by Foul Water.—Mr. Wanklyn, the English analyst, examined water from a well at the Leek Workhouse, and found it to contain .02 parts of free ammonia, and .34 parts of albuminoid ammonia per million of water. Of this occurrence he says, "In the Leek Workhouse there has been for years past a general tendency to diarrhœa, which could not be accounted for until the water was examined and shown to be loaded with vegetable matter." He adds, "A well on Biddulph Moor, a few miles from Leek, yielded .05 grain chlorine per gallon, and .03 free, and .14 albuminoid ammonia per million. The persons who were in the habit of drinking this water suffered from diarrhœa."*

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*"Dissolved or suspended organic matter, whether of vegetable or animal origin, will cause diarrhœa. In the recent war, great numbers of cases occurred from the use of marsh or ditch water; the sickness ceased when wells were sunk."

"Mineral matters, either dissolved or suspended, will give rise to it if present in considerable quantity."

"Water impregnated with nitrate of lime will produce diarrhœa. Brackish water will act in the same way."

HUXLEY & YOUMANS.

Suspended Matters in Well Waters. — Well waters are often contaminated by the entrance of foreign matters because the openings are not sufficiently protected. The author has examined many specimens of water from wells so exposed, and is convinced that reckless carelessness exists as to protecting the wells from dust, and the like. Nearly one-third of the

Fig. 82.
Suspended matters in well waters.

waters so examined have been found to contain suspended particles, which, under the microscope, reveal themselves (figure 82) as partly decayed fibres of straw; cotton; wool (*c*); hair (*e*); pollen grains from plants (*b*); spores of fungi; scales of butterflies and moths (*a*). Dr. Parkes, of London, referring to the results of his examinations of water in that great city, says, "Fibres of cotton, wool, or linen, starch cells

(figure 82, *f*) macerated paper, human hairs, yellow globular masses, and striped muscular fibre (undigested meat) (*d*), with squamous epithelium cells, are all indicative of contamination of the water with human refuse, and most probably with sewage."

Living Organisms in Water.—"Amongst these

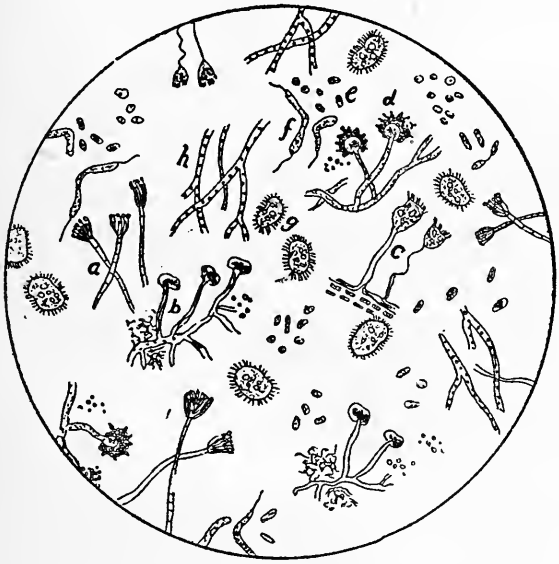

Fig. 83.
Living organisms in potable waters.

matters and feeding on them," continues Parkes, "will probably be found living organisms of low types, such as bacteria (micrococci, bacilli, and vibriones), amœbæ and infusoria. These organisms are not in themselves dangerous, but they indicate the presence of matters, chiefly organic, upon which they feed, and amongst them may be those germ-producing organisms which so often find their way into sewage." The ac-

companying sketch (figure 83) shows a few of the living organisms reported as having been found in potable waters; *a*, represents a species of green mold (penecillium); *b*, another form of mold (mucor); *d*, a fungus (aspergillus); *e* and *f*, forms of bacteria (micrococcus, bacillus, and vibrio); *c*, a simple form of animal belonging to the protozoans (vorticella); *g*, another protozoan (paramecium).

REVIEW.

1. Which are the most injurious of the ordinary impurities of potable waters?
2. State what you know of the average amounts of mineral impurities ordinarily allowable in water used for drinking.
3. What is organic matter?
4. In what forms is the organic impurity of water usually determined in chemical analysis?
5. What do you know of the opinions of chemists as to the limits of organic impurity ordinarily allowable in potable waters?
6. Give instances, principally local, of the occurrence of organic impurity in water.
7. What do you know of the significance of chlorine in water?
8. Give instances of the amount of chlorine occurring in different waters.
9. Wherein lies the danger of organic contamination of water?
10. Give known instances of bodily disorders resulting from the use of water so contaminated.
11. What do you know of the possibility of disseminating typhoid fever through the medium of foul water?
12. Enumerate some of the mechanically suspended impurities to be found in exposed waters.
13. What do you know of the occurrence of living organisms in water?

CHAPTER 21.

SIMPLE TESTS FOR PURITY IN POTABLE WATER.

Chemical Analysis of Water.—In cases of suspected water contamination, a sample should be submitted to a competent chemist for analysis. He will certify to the state of purity in the sample, and as to the possibility of bettering the water by any simple means. From him the following items of information should be asked:

1. The total amount of solid matters present.
2. The nature of the dissolved solids. If possible a full analysis of the solids should be made, and in all cases the predominating metals should be determined, and the nature of the prevailing salts, whether carbonates, sulphates, or chlorides.
3. The degrees of hardness, expressed as total hardness, temporary hardness, and permanent hardness.
4. The amount of chlorine present.
5. The amount of nitrogenous organic matter determined as free ammonia and albuminoid ammonia.
6. The presence or absence of deleterious gases.
7. The presence or absence of poisonous metals.
8. The nature of the mechanically suspended matters.

Tests of Purity in Water.—From such facts, the general condition of the water can be inferred.

However, it is not always possible to secure the aid of chemical skill in examining drinking water; it is proper therefore that we become acquainted with at least a few of the determinative tests to which water can be subjected. The following observations may be made by any one with practice and scrupulous care, and by such assistance much reliable information as to the purity of any water may be gained.

1. *Color.* It is a common statement that pure water is colorless; this, however, is strictly true of small bodies of water only; for when viewed through great depths, the purest of water possesses a distinctly bluish tint. To determine the color of a potable water, fill with the sample a tall cylinder or bottle of clear white glass; cylinders made for the purpose, about two feet in length are best adapted. Place the vessel on a white dish, or a sheet of white paper, and carefully examine, looking from the surface downward. Good waters will show the bluish tint above referred to; any large amount of vegetable impurity will give a greenish color; and sewage filth will tint the water yellow or light brown. If salts of iron are present in the water, the last named indication will be unreliable, as such salts themselves would give to the water a brownish hue.

2. *Clearness.* Examine as for color; also hold the vessel containing the sample toward the light; then view it when held before some black object. Any turbidity is an indication of the presence of organic impurities in solution, or of suspended solid matters. All turbidity is a sign of contamination, though the op-

posite must not be inferred—that clear water is necessarily pure. There is a wide-spread popular error on this point, and it has led to the use of very foul waters because of their sparkling appearance. One of the clearest waters ever examined by the writer, was taken from a pump in Greenwood Cemetery, Brooklyn, N. Y.,* yet it was found to be heavily laden with nitrates, which, doubtless, were derived from the bodies there entombed.†

3. The *Odor* of drinking water is an important

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*A number of pumps are to be found in that wonderful and beautiful city of the dead, and I have looked with horror upon visitors drinking from these grave-fed wells. Such water is highly charged with the nitrates and nitrites of decomposing flesh, and water so impregnated has a cooling, saline taste, very pleasant to the palate of the blissfully ignorant drinker, and sure to excite subsequent thirst, which will lead to continued draughts. During another visit to Greenwood in the summer of 1889, I was glad to see that a notice had been placed over each of the pumps, stating that the water was to be used for irrigating the flower beds only: but the pumps are still there with the levers free, and visitors continue to drink at them. Should we marvel that the silent metropolis is so well tenanted?

†The London *Lancet* in referring to water so contaminated, says: "It is a well ascertained fact, that the surest carrier and the most deadly fruitful nidus of zymotic contagion, is this brilliant, enticing-looking water, charged with the nitrates which result from decomposition."

Johnston says of such waters: "The water of a well close to the old churchyard on the top of Highgate Hill was examined by the late Mr. Noad, and found to contain as much as 100 grains of solid matter to the gallon, 57 grains of which consisted of the nitrates of lime and magnesia. This large amount of nitrates is traced to the neighboring graveyard, as such compounds are generally produced where animal matters decay in porous soils. * * * While the buried bodies were more recent, animal matters of a more disagreeable kind would probably have been found in the well, as I have myself found them in the water of wells situated in the neighborhood of farm-yards."

characteristic. To determine it, procure a quart bottle; see that it is clean and provided with a well-fitting cork. Half fill the bottle with the water under examination; cork the vessel and set it aside in a warm place for a few hours; then shake it well, open and smell. Any perceptible odor should condemn the water for domestic use until a determinative analysis has been made. If no odor is perceptible after gentle warming, the water should be heated nearly to boiling, the odor being tested at frequent intervals as the heating proceeds. Remember that pure water is odorless.

4. *Taste.* Water intended for household use should be entirely devoid of taste. Any perceptible flavor should be considered as strong evidence that the liquid is contaminated, and chemical tests should be employed. As many mineral ingredients impart but a feeble taste to water, these tests must be made with critical care. Many waters that seem tasteless while cold develop a positive taste if gently warmed. Do not consider the flat insipid nature which all ordinary water acquires by boiling, as a proof of contamination.

5. The *presence or absence of Chlorine* should be next determined. This can be satisfactorily done by a competent chemist only, though the method of proceeding is simple. A drop of pure nitric acid and a few drops of clear silver nitrate solution are to be added to the water under test. A milkiness or turbidity is due to the formation of silver chloride, and is a proof of the presence of chlorine, in the sample. As was stated on page 214, the presence of chlorine in mod-

erate quantity is a sign of danger only when associated with organic matter.

6. The *presence of Organic Matter* in water is difficult to determine, except by complicated chemical tests. Yet such determination is of utmost importance in deciding upon the wholesomeness of water. Much information upon this point, however, may be gained from the tests on color, odor, and taste as before described. Heisch's test for organic impurity in water may be made as follows: "Fill a clean pint bottle three-fourths full of water; dissolve a teaspoonful of loaf or granulated sugar; cork the bottle and set it in a warm place for two days. If the water becomes cloudy or muddy it is unfit for domestic use. If it remain perfectly clear it is *probably* safe to use." Some waters contain so much organic filth that when boiled the polluting substances coagulate, as does the white of an egg when heated; when the water cools the impurities separate in flocks.

REVIEW.

1. What are the chief chemical data on which to base an opinion as to the wholesomeness of any sample of water?
2. State the significance of color in water.
3. How would you examine a sample of water to ascertain its color?
4. What is the significance of clearness of potable water?
5. Show that clear water is not necessarily pure.
6. Explain the significance of odor in drinking water.
7. Give details of testing a sample of water for odor.
8. Show the significance of taste in potable water.
9. How may water be tested for chlorine?
10. For organic impurities?

CHAPTER 22.

PURIFICATION OF WATER.

THE fact that water becomes so readily contaminated with both organic and inorganic impurities, gives great importance to the subject of water purification. Many methods of improving the qualities by simple treatment have been proposed and practiced.

Purification by Boiling.—For operating on a small scale, as for domestic purposes, boiling has long been in favor. This treatment may produce important changes in potable water. For example, consider a specimen of water possessing great temporary hardness, and moderately contaminated with organic refuse. As the boiling proceeds, the dissolved gases of the water, among them the carbon dioxide, which is sure to be present in such a sample, will be expelled; the lime carbonate, from which the water derived its quality of temporary hardness will separate from solution, and fall as a sediment, leaving the water comparatively soft. This is the easiest and the cheapest known method of softening on a small scale such lime-carbonate waters.

Another probable result of the boiling will be the coagulation and consequent separation of certain forms of organic matter. Farther than this, the boiling temperature will kill many if not all of the living

germs present in the water, thus insuring the liquid against the power of communicating specific diseases. Much discussion has arisen among scientists as to the minimum temperature that is fatal to the common forms of bacterial life, and from the facts adduced by the controversy we may conclude that the temperature of 212° F. will effectually destroy all living organisms found in water, except possibly the spores of certain bacteria, and these may be surely killed by boiling the water several times at intervals, allowing time between the boilings for the spores to develop. Parkes declares his belief that there is scarcely any doubt that the specific poisons of cholera, enteric fever, and other forms of contagion such as are commonly propagated through the medium of impure drinking water, are destroyed with certainty by even a few minutes' boiling. It must be remembered however, that at great altitudes water boils at a temperature considerably below 212° F. Under such conditions of diminished heat, the certainty of destroying microscopic organisms by boiling the water is considerably lessened.

Boiled water possesses an insipidity which, to many people, is almost nauseating; this taste is due to the non-aerated condition of the water, the atmospheric gases having been expelled by the heat. Such water may be again aerated by allowing it to flow slowly from a perforated cask, or through a collander, in many fine streams.

Purification by Distillation.—Distillation is the means by which the purest water may be obtained. The process consists in boiling the water, and in col-

lecting and condensing the steam. In this way the solid ingredients are left in the boiler. The greater part of the dissolved gases will be carried off in the first part of the distillate; if this portion be rejected, the water that subsequently distills may be regarded as approximately pure.

The apparatus for distillation (figure 84) consists of

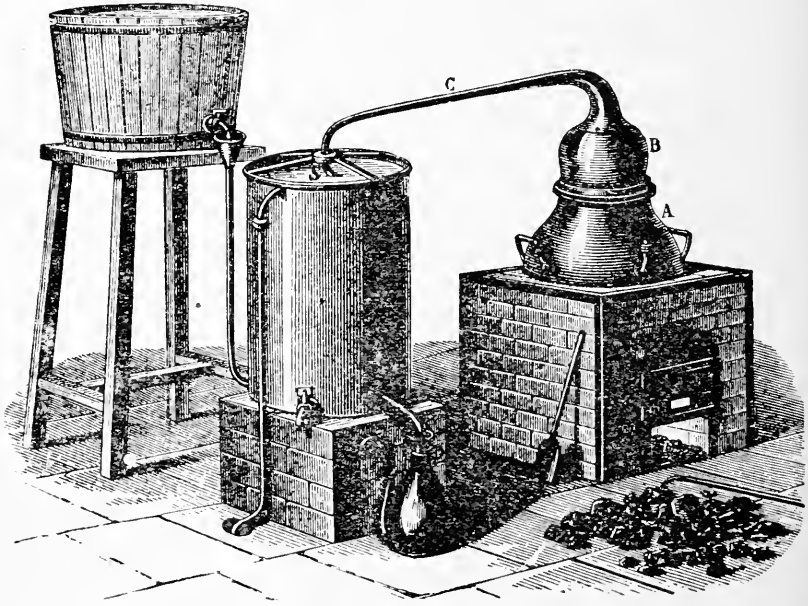


Fig. 84.
Apparatus for distillation of water.

a boiler A, with a delivery pipe B and C through which the steam is conducted to a spiral tube or worm set in a vessel of cold water S; within the spiral tube, the steam condenses to the liquid state, and this water is caught, in a suitable vessel. A stream of cold water is supplied to the condenser through an inlet tube, the surplus being carried off through an exit pipe.

For the distillation of water or other liquids on a small scale, the apparatus represented in figure 85 may be employed. In addition to its portability this has the advantage of being constructed in all its essential parts of glass. In the sketch A is a glass flask, containing water, and heated by a spirit lamp placed below; B is a delivery tube connected with the condenser C.

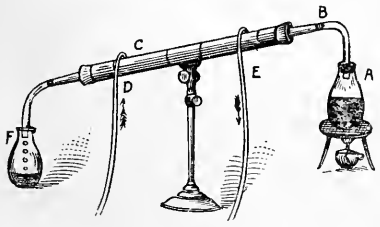


Fig. 85.
Portable distillation apparatus of glass.

This form of condenser is called from its inventor the Liebig condenser; it consists of a central tube continuous with B, and surrounded by a large outer tube, through which cold water is flowing. The central tube is thus incased in a water jacket, a continuous supply being made through D, an escape is provided through E. The distillate is caught in F.

Great care should be exercised that the distilling apparatus be clean, and of such material that the water will not dissolve appreciable amounts of its substance. Houses that are furnished with steam heating appliances may be easily supplied with a sufficiency of distilled water. Water that has been distilled with all proper precautions may be considered free from all disease germs, and therefore comparatively safe for domestic use. Before such water can be relished for drinking purposes it must be aerated, and this may be accomplished by the same means as are employed to aerate boiled water.

Filtration is often resorted to as a purifying process. Many forms of domestic filters are now in the market. The manufacturers of these devices usually guarantee them to free the water from all suspended and dissolved matters; but such extravagant claims are seldom realized in practice. The commonest form of water filter consists of a vessel of wood, stone, or metal, containing a slab of porous earthenware, and layers of charcoal, magnetic iron oxide, and gravel; in some filters pounded glass and sponge are used. Through this the water is allowed to percolate, thus imitating in a feeble way the grand processes of natural filtration in which foul waters become sweet by percolating through the porous strata of the earth. A filter which in service will prove fully as efficient as many of the high-priced articles offered in the market, may be made as follows: Provide some water-tight box, cask or jar of convenient size; bore a number of holes in the bottom of the receptacle, and place within it alternate layers of recently heated charcoal, fine gravel, and sand, till it is half or two-thirds full. Pour in at the top the water to be filtered; that which first passes through may be somewhat turbid, from loose particles derived from the filter; return such to the top. In a short time the filtered water will appear perfectly clear, though it may have been originally of the foulest kind. Such a filter is of service as long as it is clean. The great objection to the use of domestic filters is based upon the exceedingly small amount of filtering material, and the consequent rapidity with which the filters become choked. A dirty filter—one that has

taken from the water all the foul matter that it is capable of removing—is a source of pollution to the water that subsequently passes through.

The process of filtration is a serviceable one, and could it be successfully performed with an apparatus of adequate size, it would be regarded as a very efficient aid in the purification of water. The writer has examined many forms of household filters, and has analyzed samples of water both before and after filtration through such; and he is convinced that most of the filtering devices require for cleanliness far more care and attention than the ordinary house-keeper is inclined to bestow upon them. And if not cared for, they become sources of positive danger.

A domestic filter of recent invention and one of the best yet offered, is the *Pasteur-Chamberland* device. In this the water is forced through several partitions of porous earthenware, by which treatment it is entirely freed from bacterial organisms. Water filtered in this apparatus is completely sterilized, though its dissolved solids are not diminished. Difficulty is experienced in cleaning this filter.

A filter, even when working in the best manner possible, cannot separate from water its dissolved matters; charcoal, it is true, will take out some portion of the ammonia and other gases, but the removal of these is in no case complete, and the amount of dissolved solids is in no way diminished by filtration.

Filtration on a Large Scale.—For the removal of mechanically suspended matters, such as clay, mud, and sand, the filtration process proves of great service;

and in the purification of water on a large scale, as for a city supply, filtration is an indispensable part of the treatment. The water of London is filtered by being passed through beds of sand and gravel. The average thickness of the sand layers is three feet; beneath this are strata of gravel, the coarseness increasing with the depth. The water upon the filter beds is never allowed to exceed two feet in depth. In practice it is found necessary to frequently renew the upper layers; the rapidity with which the filters become choked is surprising.

Chemicals as Purifying Agents.—It is claimed that certain chemical substances when added to water exert a purifying effect upon it. Of these *Alum* is perhaps in commonest use. When mixed with certain waters, alum forms a bulky, gelatinous precipitate of aluminium hydrate, which in settling carries with it much of the matter held in mechanical suspension. Good authorities recommend about six grains of alum to the gallon of water as the best proportion. The waters of the Seine are used in Paris after clarification by this simple process.*

*"For household use, on a small scale, water can be easily clarified and purified by placing a layer of clean cotton two or three inches deep at the bottom of a glass percolator, such as is used by druggists, and pouring the water to be filtered, to which the solution of alum has been added, into the percolator, and allowing it to drip through into a clean vessel placed to receive it. The alum solution is conveniently made by dissolving half an ounce of alum in a quart of water, and of this solution a scant teaspoonful should be added to each gallon of water to be filtered. Alum is now used in a number of filtering and purifying systems which have of late years been brought prominently before the public by their inventors or the companies controlling them."—*Dr. W. G. Tucker, in Science*, July 15th, 1892.

Tannin exerts a coagulating effect upon certain forms of organic matter. The common way of adding the tannin is to place oak chips in the water, this kind of wood being very rich in the astringent named. This treatment is of use only if the polluting ingredients be of an albuminoid character; but in waters so contaminated the method is a very serviceable one, as the coagulum in forming entangles most of the other impurities.

Prof. Johnston states that the marshy waters of India are rendered potable by the use of a nut—*strychnos potatorum*. The powder produced by crushing the nut is rubbed on the inside of the water vessel, and the impurities of the liquid soon subside. The same authority reports that in Egypt the muddy water of the Nile is clarified by the addition of bitter almonds.*

Softening Hard Waters.—For softening waters possessing a high degree of temporary hardness, the value of the boiling process has been already pointed out. This mode of treatment, however, is inapplicable on a large scale; and a much cheaper method has been devised. This is known as *Clark's process*; it

*It is well to read here the experience of the Israelites—Exodus xv, 23-25:

"And when they came to Marah, they could not drink of the waters of Marah, for they were bitter: therefore the name of it was called Marah.

"And the people murmured against Moses, saying, What shall we drink?

"And he cried unto the Lord: and the Lord showed him a tree, which when he had cast into the waters, the waters were made sweet; there he made for them a statute and an ordinance, and there he proved them."

consists in adding lime water to the water that is to be softened. It may appear to be a strange proceeding, to add lime for the purpose of removing a compound of lime, yet the explanation of the operation is simple. As already explained, it is mostly lime carbonate that gives to water the property of temporary hardness; and this substance is scarcely soluble at all in pure water; but it dissolves with ease in water containing carbon dioxide. Now the lime that is added to such a carbonated water will unite with the free carbon dioxide there present, forming with it insoluble lime carbonate; at the same time the carbonate originally in solution will fall as a sediment because the removal of the free carbon dioxide robs it of its solvent. In this way it is possible to reduce the hardness of water 70 or 80 per cent. The addition of the lime water causes a turbidity throughout the liquid, and time must be allowed for the sediment to subside before the water can be used. In Porter's modification of Clark's process, the water is filtered under pressure, the solid particles being thus more speedily removed.

REVIEW.

1. Name the principal methods of artificially purifying water.
2. Show the effects of boiling in improving the quality of water.
3. Explain the insipidity of boiled water.
4. What is distillation?
5. Describe the process of distilling water on a large scale.

6. Describe the Liebig condenser and its attachments for distillations on a small scale.

7. What do you know of filtration of water as a purification process?

8. Describe an ordinary domestic filter.

9. Describe the Pasteur-Chamberland filter.

10. Show the imperative need of keeping a domestic filter clean.

11. Explain Clark's process of softening waters.

12. Explain Porter's modification of this process.

13. Name the principal chemical substances known to exert a purifying effect on water.

14. Explain the effect of alum. Of tannin.

CHAPTER 23.

MINERAL WATERS.

Classification of Mineral Waters.—The term mineral water is applied to any natural water that contains so large a proportion of mineral ingredients as to derive therefrom a characteristic taste. No clear distinction, other than this, exists between potable and mineral waters. According to their prevailing ingredients, mineral waters are usually classified as sulphur waters, carbonated waters, chalybeate waters, alum waters, siliceous waters, and saline waters. We will briefly consider each of these kinds.

Sulphur Waters contain a considerable quantity of hydrogen sulphide, and this gas possesses such an unmistakable odor that no chemical skill is needed to determine its presence. The solid contents of such waters consist mostly of alkaline sulphides and sulphates. Utah furnishes many remarkable examples of sulphur springs. The waters of the Warm Springs and of the Hot Springs at Salt Lake City are rare and wonderful mixtures.

Carbonated Waters are such as contain an abundance of carbon dioxide gas, by virtue of which they dissolve large amounts of calcium carbonate and of other carbonates. Carbonated waters are of two kinds: those containing much lime in combination are known as calcium waters; and waters containing iron com-

pounds as predominating ingredients are known as chalybeate waters.

Calcium Waters.—It has been already shown that the solvent power of water for gases is increased by pressure, and we may conclude from this, that, within the crust of the earth, waters coming in contact with carbon dioxide would take into solution large proportions of the gas. This addition gives the water power to dissolve many mineral carbonates, of which limestone or calcium carbonate may be taken as a type. As such highly charged water reaches the surface as springs, the undue pressure being relieved, most of the carbon dioxide escapes, in consequence of which the lime carbonate falls from solution in the solid state. This may be deposited in such quantities as to form a curb of stone around the spring, and to incrust articles immersed in the water. Very remarkable carbonated springs exist at Soda Springs, Idaho, and at Midway, Utah. At the former place the waters are so highly charged with carbon dioxide that the escaping gas keeps the springs in constant and violent agitation. Any article placed in the water soon becomes coated with a deposit of lime carbonate. Such process is sometimes incorrectly spoken of as petrifaction; it is simply an incrusting or covering, not a replacing by stone. A bunch of grapes or a bouquet of flowers may be completely covered in this way, and long after the soft fruit and the delicate petals have decayed, the stony casing remains, preserving the full form of the original.

Chalybeate Waters contain iron in the form of

ferrous carbonate. This substance is soluble in water containing free carbon dioxide, but not in pure water; in this respect it resembles the lime carbonate already referred to. When the carbon dioxide escapes from such water, the iron carbonate is deposited from solution; under the influence of atmospheric oxygen, however, this soon changes to ferric oxide, and appears about the springs, and upon objects placed in the water, as a red or yellow incrustation. Typical illustrations of this class of waters are found in Sevier Co., and in Millard Co., Utah. At the former place the deposits of ferric oxide are so pure and plentiful as to be used with very little preparation for making paints.

Alum Waters are rich in iron and aluminum sulphates, and frequently contain small quantities of free sulphuric acid. The strong styptic taste of alum is characteristic of such waters. Alum springs are not of common occurrence in the west.

Siliceous Waters contain silica in solution, and are usually alkaline and always hot as they naturally occur in springs. Hot alkaline water appears to be the natural solvent of silica. Of this kind of thermal springs are geysers, the most noted of which occur in the Yellowstone Park of our own country; others exist in Iceland and in New Zealand. As the water escapes from confinement, and as it cools, much of the silica is deposited from solution, thus forming the geyser craters.*

*In some places the silica is deposited in a gelatinous condition to a depth of three or four inches. Trunks and branches of trees immersed in these waters are quickly petrified. LE CONTE.

Saline Waters contain many earthy salts, among which the chlorides of sodium and calcium predominate. The celebrated Kissengen Springs in Germany belong to this class, as do also the famous Saratoga Springs in the United States. To this division of mineral waters belong also the waters of the ocean, and of salt and alkaline lakes. The composition of saline waters is very complicated; indeed sea water contains all soluble compounds that are found in the earth, and that are capable of existing together in the same solution. The prevailing ingredient is sodium chloride.

A very concentrated saline water is that of the *Great Salt Lake*, which contains on an average about 19 per cent. by weight of solid ingredients, or say 13,000 grains per gallon of water. The author collected and analyzed a sample of Salt Lake water in December, 1885, and found in it the following ingredients:

	Grams per litre.	Per cent. by weight.
Sodium chloride -	152.4983	13.5856
Sodium sulphate -	15.9540	1.4213
Magnesium chloride	12.6776	1.1295
Calcium sulphate -	1.6679	0.1477
Potassium sulphate	4.8503	0.4321
Total solid matter	187.6481	16.7162

The proportion of solid matters in an inclosed body of water like the Great Salt Lake is variable according to the prevailing climatic conditions. Thus, during the dry and warm season, evaporation proceeds much more rapidly than water is supplied by the inflowing streams, consequently at such times lake

water becomes more concentrated. During the wet months, however, the supply far exceeds the loss by evaporation, and the water becomes correspondingly diluted. As a basis for comparison with the above figures, there are given below the results of an analysis of lake water collected in August, 1889:

	Grams per litre.	Per cent. by weight.
Sodium chloride	182.131	15.7430
Sodium sulphate	12.150	1.0502
Magnesium chloride	23.270	2.0114
Calcium sulphate	3.225	.2788
Potassium sulphate	5.487	.4742
Total solids	226.263	19.5576

In 1892 the lake water was even more concentrated. The average of four analyses of samples taken from the lake in September of that year showed the water as holding in solution 250.75 grams per litre, or over 22 per cent. by weight.

The water of the *Dead Sea*, in Palestine, is still more concentrated. An analysis of a sample of Dead Sea water collected at a depth of 1,110 feet, by Capt. Lynch, showed the following composition:

	Per cent. by weight.
Sodium chloride	7.555
Potassium chloride	0.658
Magnesium chloride	14.889
Calcium sulphate	0.070
Calcium chloride	3.107
Potassium bromide	0.137
Total solids	26.416

Temperature of Springs.—The average temperature of spring water is from 60° to 65° F., but min-

eral springs often far exceed this. Indeed some mineral waters are discharged from the spring at a boiling temperature. The Hot Springs, near Salt Lake City, have a temperature of 128° F. The Monroe Springs, in Sevier Co., Utah, discharge water at 137.5° F., and certain hot springs, near Draper, Salt Lake Co., Utah, emit water at a temperature of 158° F. The constancy of temperature in most of these springs is remarkable. Wells says: "There is evidence to show that the temperature of some hot springs has not diminished for upward of a thousand years."

Medicinal Effects of Mineral Waters.—Before leaving the subject of mineral waters, reference should be made to the common belief that all such waters are of necessity valuable remedial agents in disease. Indeed, there seems to be a popular belief that any natural water possessing a particularly disagreeable taste or odor is surely good for the body. It is an undeniable fact that many mineral waters possess great therapeutic properties; especially are they valuable for washing and bathing in cases of skin disease, gout, and rheumatism, and in rare cases it may be wise to administer the waters internally; but there is a reckless carelessness now existing as to the use of such waters. They should be used in moderation and under skilled direction. Mineral water is to be regarded as a medicine, not as a panacea; and if administered unwisely the water may prove positively harmful.

REVIEW.

1. What is mineral water?
2. Give a general classification of mineral waters.
3. Give general characteristics of sulphur waters, with local illustrations.
4. Give characteristics of carbonated waters, with illustrations.
5. What sub-classes of carbonated waters are you acquainted with?
6. What do you know of carbonated waters containing lime?
7. Of chalybeate waters?
8. State what you know of alum waters.
9. Of saline waters, with some notable examples.
10. What do you know of the average solid contents of the water of Great Salt Lake?
11. Name the principal mineral ingredients of the Salt Lake.
12. Illustrate and explain the fluctuation in the proportions of dissolved solids to which the Salt Lake is subject.
13. What do you know of the Dead Sea water?
14. State what you know of the temperature of spring waters.
15. What is your opinion of the medicinal value of mineral waters?

CHAPTER 24.

COMPOSITION OF PURE WATER.

Chemical Elements and Compounds.—Knowing now that natural waters are never pure, and having considered the process of distillation, by which chemically pure water may be prepared, it would be well to enquire concerning the nature and composition of this purest kind of water. From the earliest times of which we have general record till near the end of the eighteenth century, water was thought to be an element; now it is known to be a compound. Elements are simple substances, such as man has never yet decomposed into other constituents; a compound, however, is composed of at least two elementary substances. As illustrations: gold, silver, iron, nitrogen, carbon, oxygen, sulphur, are elements; for not one of them has ever been decomposed by man. Thus far no chemist has been able to produce from pure gold anything but gold; and so with each of the elements, of which now between 60 and 70 are known. On the other hand, common salt is an example of a compound; it may be separated by chemical means into the two elements sodium and chlorine; carbon dioxide is also a compound, it consists of carbon and oxygen. So, too, water is a compound, for it may be decomposed into the two ingredients, hydrogen and oxygen.

Electrolysis of Water.—The decomposition of

water may be very beautifully and instructively illustrated by passing a voltaic current through a quantity of water, and collecting the gases that result. If an apparatus similar to that shown in figure 86 be employed, the collecting tubes being filled with water and inverted over the terminations of the conducting wires

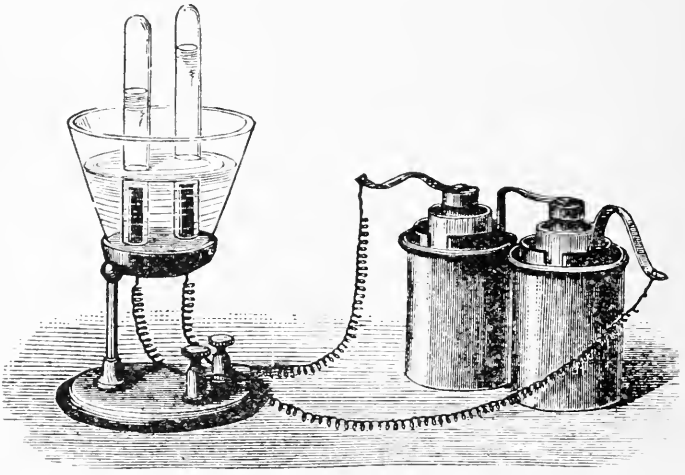


Fig. 86.
Electrolysis of water.

from the battery on the right, bubbles will be seen rising in the tubes as soon as the current is started. One tube is seen to fill as fast again as does the other. The double quantity of gas will be proved by investigation to be hydrogen, and the gas in the other tube to be oxygen.

Decomposition of Water by Hot Iron.—If steam be passed through an iron tube containing scraps of iron heated to bright redness, the vapor will be decomposed, its oxygen combining with the metal in

the tube to produce an oxide of iron, and the hydrogen escaping at the open end of the tube, where it may be collected. By this method also we prove that water consists of the elements hydrogen and oxygen.

Oxygen.—The general mode of preparation and the principal properties of oxygen have been briefly considered in a preceding chapter (see pages 42 and 43). It will be well at this stage to review the subject and re-read the pages referred to.

Hydrogen; its Preparation.—Hydrogen, however, is to us a new element. To investigate its properties we should prepare it in larger quantity than will be yielded by a weak battery current in water. The simplest and for our present purpose the best mode of preparing the gas is as follows: Arrange a generating bottle, with funnel, delivery tube, pneumatic trough, and collecting bottle. The apparatus shown in figure 3, page 13, will answer our purpose well. Place within the bottle some scraps of zinc; then adjust the cork and pour into the bottle through the funnel tube enough dilute sulphuric acid* or muriatic acid to cover the bits of zinc to the depth of an inch. Gas will soon collect in the inverted bottle; discard the first bottleful; it is mixed with air; then collect several bottles of the gas.

*Care must be exercised in diluting sulphuric acid, as great heat is developed in the process. The acid and the water should be measured separately—one volume of the former to three of the latter; the acid should then be poured in a small stream into the water, which in the meanwhile should be vigorously stirred. The mixing must be done in a vessel of glass or earthenware, as the acid will attack wood and metal. Remember that suphuric acid is intensely corrosive and poisonous.

Properties of Hydrogen.—By collecting and examining the hydrogen we shall find it to be a colorless gas, and if pure it will be devoid of odor, though the impurities of the materials used in its manufacture usually impart to the gas a disagreeable smell. It is also very light, exerting a buoyant effect on the vessels within which it is confined; in fact, hydrogen is the lightest known substance. Its buoyancy may be prettily tested by filling with the dried gas a child's toy balloon; when released this will rise swiftly through the atmosphere.

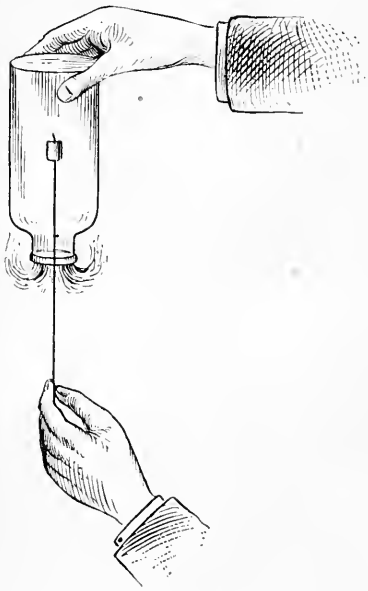


Fig. 87.
Hydrogen burning.

Hydrogen is also inflammable; it may be burned at the mouth of the bottle, as shown in figure 87. Another demonstration of the combustible nature of hydrogen may be made by passing the gas through a tube drawn at one end to a jet. The gas as it issues may be burned in a continuous flame.

Synthesis and Analysis of Water.—While the hydrogen jet is burning, invert over it a cold dry bottle containing air or oxygen. A mist appears on the inside and drops of liquid may collect there. The combustion of hydrogen then marks a combination

between this gas and the oxygen of the atmosphere, the result of the union is water. We have thus proved the composition of water by *synthesis* as well as by *analysis*. By analysis, or decomposition, we have separated the water into its elements, hydrogen and oxygen; this we accomplished by the aid of the voltaic current, and through the agency of heated iron. By synthesis, or union, we have combined the elements and produced the compound, water.

It is remarkable that hydrogen, which burns with a very intense heat, and oxygen which is so vigorous a supporter of combustion, by their union should form a compound possessing the property of extinguishing fire. When oxygen and hydrogen are brought together in quantity, and a flame or an electric spark is applied to the mixture, a very violent explosion occurs, and water is produced by the union of the gases.

The Oxy-hydrogen Flame.—If a stream of oxygen be forcibly driven into the midst of a flame of burning hydrogen, the oxy-hydrogen flame is produced; this is attended by the most intense heat known to be produced by chemical processes. In such a flame, steel wire will burn like wood in an ordinary fire; zinc, copper, and all known metals may be deflagrated, many of them with characteristic flame tints; even platinum, the most infusible of metals, may be readily melted by this means. Yet the flame is practically non-luminous; its great heat may be utilized, however, in raising some incombustible solid to a state of incandescence. A piece of lime or of magnesia introduced into the flame is at once brought to a state of

dazzling brilliancy. This is known as the *calcium* or *Drummond light*, and is of great service in the operation of optical lanterns, and in other cases wherein a particularly brilliant illumination is desired.

Constancy of Composition.—As a result of accurate experiments we know that pure water consists of:

	By volume.	By weight.
Oxygen - - -	1 part	8 parts
Hydrogen - - -	2 parts	1 part

These proportions are invariable, as indeed are the proportions of the constituent parts in any compound. In accordance with some great principle, which the mind of man has not fully comprehended, the elements of matter unite in fixed and unchangeable proportions. The discovery and proof of this fact is one of the greatest achievements of modern science. Not only is there order and system in the world of living things; but even the dead minerals of earth, and the water of ocean and air, each is compounded according to unchanging law.

REVIEW.

1. Explain the difference between a chemical element and a compound.
2. Show the difference between a compound and a mixture.
3. Describe a demonstration of the compound nature of water.
4. How may steam be decomposed?
5. Review the preparation and properties of oxygen (see chapter 3).
6. How would you prepare hydrogen for experimental purposes?

7. State the chief physical properties of hydrogen.

8. Describe demonstrations of some chemical property of hydrogen.

9. Explain the chemical results of the combustion of hydrogen in air.

10. Define and illustrate "analysis"; "synthesis."

11. Explain the Drummond or calcium light.

12. Describe the result of applying a flame to a mixture of oxygen and hydrogen.

13. By what other means may union be effected in such a mixture?

14. State the composition of pure water.

15. Show the constancy of composition of chemical compounds.

PART III.

FOOD AND ITS COOKERY.

CHAPTER 25.

FOOD—ITS NATURE AND USES.

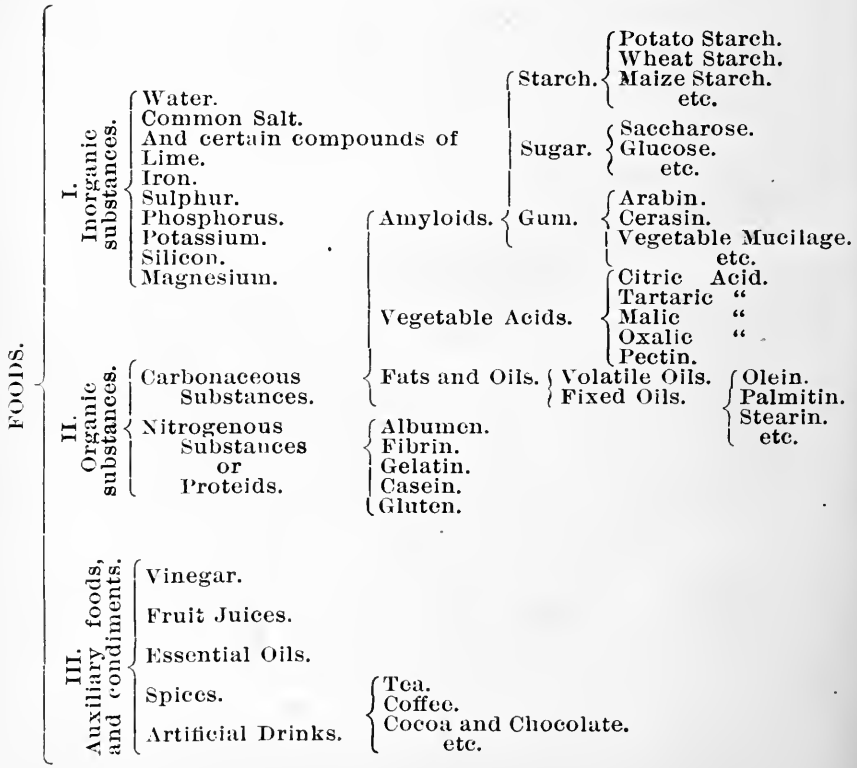
Bodily Need of Food.—Chemical analysis has demonstrated that the human body consists of at least fourteen separate and indispensable elements. These are nitrogen, carbon, oxygen, hydrogen, phosphorus, sulphur, sodium, potassium, calcium, magnesium, iron, silicon, chlorine, and flourine. Of these the first four are by far the most plentiful within the body. It is known that the organs of the living body are in ceaseless action, whereby great expenditure of force occurs, with consequent loss of material. It is therefore necessary that the system be supplied with material from which to repair its various parts; such supplies we called *Food.*

What is Food? — The term food may then be applied to substances that, when taken into the body, serve to nourish its tissues, and sustain its vital energy.* A perfect food would be one that contained all of the elements of the body in a digestible condition, and in the proper proportion to supply the various tissues of the body. Such a food-stuff is not known. Milk approaches this ideal standard, yet the

*"Foods may be defined as substances which, when taken into the alimentary canal, are absorbed from it and there serve either to supply material for the growth of the body, or for the replacement of matter which has been removed from it, either after oxidation or without having been oxidized." MARTIN.

proportions in which the elements are present in milk fit it to be a complete food only for infants; it is deficient in many of the substances required by adults. From these statements we will perceive at once the necessity of employing a mixed diet, in which we may supply with one article the elements lacking in another.

Classification of Foods.—According to composition, alimentary substances, or the simple constituents of foods may be classified as follows:



Mixed Foods.—A well-regulated dietary should include a proper amount of each of these classes of food; and by an instinctive tendency we select and combine foods, to accomplish this purpose. As an example, bread is rich in starch, a compound of the amyloid group; it contains a small proportion of gluten, which is a nitrogenous compound; but it is very deficient in fat; however, we are prone to add butter to our bread, thereby supplying the chief lack. But bread and butter is an incomplete food; it is still poor in nitrogen, and we usually endeavor to add a nitrogenous element, such as meat or eggs, at our meals. Potatoes are rich in carbon and hydrogen, and in many of the mineral salts of food; yet they are very deficient in nitrogenous substances, and we relish them best with meat.

Moderation Needed in Animal Diet.—It is beyond doubt that many people indulge too freely in animal foods; and others have adopted an intemperance of an opposite kind, by abstaining from animal matters entirely. Nitrogenous foods we must have, and these are advantageously supplied through the medium of animal products. It is not necessary that flesh be frequently eaten; milk, butter, cheese, and eggs are rich in albuminoids. The indications of chemical and physiological science, and above these, the voice of reason and the experience of the human race, declare that though excessive indulgence in animal food is highly injurious, yet strict vegetarianism is not a proper course.

The Quantity of Food needed for proper bodily

support varies widely in different persons. The state of the person's health, the amount of exercise taken, the climate, and many other circumstances unite to regulate the demand for food. The natural appetite, unvitiated by improper habits, weakening deprivation, or unwarranted excesses, is one's best guide. From numerous observations, in many climes and on persons of different temperaments, it is believed that the *average* individual requirements call for 23 ounces dry solid matter, and 70 to 80 ounces of liquid per day. Dr. Hutchinson places the average daily quantity of food and drink for a healthy man at 6 pounds; and divides this amount as follows: three and one-half pounds from the mineral kingdom, including water and salt; one and one-half pounds from the vegetable kingdom, including bread, vegetables, and fruits; and one pound from the animal kingdom, comprising meat, eggs, butter, and such.

Digestibility of Food Stuffs.—Not all substances containing the elements of the human body are fitted for use as food-stuffs. A food must contain the essential elements already named, *in digestible condition*. As an example of this necessity, consider the case of carbon, which forms so large a proportion of most of our ordinary food materials, and is so indispensable to the well-being of the body. Carbon in its purest and uncombined state* is entirely indigesti-

*The purest carbon exists in a crystalized form as the diamond. Other forms of uncombined carbon are graphite or plumbago (the "black lead" of pencils), charcoal, coke, gas-carbon, and lamp black. Though these consist almost entirely of this essential element of food, yet they are indigestible and consequently unfitted for diet.

ble, and consequently valueless as food. A lump of charcoal contains far more carbon than does the same weight of bread; yet the carbon of the bread may be assimilated within the body and become part of the tissues; whereas charcoal, if introduced into the stomach, would serve mainly to derange the digestive functions. Another example,—nitrogen is abundantly present in the muscular tissues, and in some proportion it is present in all the bodily parts; there is consequently a great demand for this element. The air about us contains nitrogen to the extent of four-fifths of its entire bulk; yet this atmospheric nitrogen is valueless as a food; it enters the body at every respiratory inhalation, and escapes unchanged when the breath is expelled. Free nitrogen is not assimilated by the tissues; indeed the body seems unable to use the chemical elements as food, until they have been brought together as compounds through the agency of plant or animal life.

Plants Supply Food.—This is true of all human and animal bodies; they cannot live on unorganized matter; plants may absorb and assimilate mineral substances, but animals do not possess this power. In our own bodies we can use comparatively complicated materials only,—substances that have been already organized under the influences of life. It is a natural law that men and animals shall be supported by the plant kingdom;* if they feed upon animal bodies, these have been nourished by plants, so that their sub-

* "Plants may be considered as the laboratory in which Nature prepares aliment for animals." RICHERAND.

sistence comes directly or indirectly from the vegetable kingdom.

Food-stuffs Must be Readily Soluble.—Now we may very properly ask, what are the essentials of this condition of digestibility in food materials? In the first place, to be available as food, substances must be readily soluble in the digestive fluids. This dissolving action may be in some degree imitated outside the body. Chemical mixtures have been prepared, analogous in composition to the digestive juices; and in these, food materials have been dissolved. Thus one part of the digestive process may be carried on in glass flasks before our eyes. Any soluble substance may be thus dissolved; the artificially prepared mixture acts alike on all soluble matters. Not so, however, with the body; its digestible apparatus is more complicated than a mere collection of vessels and tubes; it is a sensitive, living organism, and rejects food that is not pleasing to the senses.

Foods Must be Palatable.—A food preparation that excites disgust in the mind* will be digested only with difficulty, and in some cases not at all; though it may be from a chemical point of view very nutritious. Several years ago Edwards and Balzac, two French academicians, performed some noted experiments by feeding dogs on prepared food and carefully noting results. The animals were kept for days on a prepara-

* The digestive organs, as indeed is the case with all other bodily parts, are readily affected by the varying conditions of the mind. Many a person while eating with relish, has suddenly "lost his appetite" under the influence of some strong emotion, either joyous or distressing.

tion of gelatine soup mixed with bread,—chemically speaking a very nutritious diet, though almost devoid of flavor. After a few meals of this stuff, the dogs evinced decided dislike, and finally refused to eat more of the insipid mess though they were suffering the pangs of starvation. The experimenters then mixed with the daily allowance of gelatine about two tablespoonfuls of meat-broth; this gave to the soup a pleasing flavor; the dogs ate ravenously of it. One animal that had already lost a fifth of its weight under the pure gelatine regimen, began immediately to improve, and in twenty-three days from the time of the change in diet the creature was heavier than before the experiments were begun. Tests of a similar kind have been commenced on human beings. Men have been kept on pure chemical preparations, containing all the needed elements, but devoid of attractive savors; and it is beyond doubt that, had the trials been sufficiently prolonged, fatal results would have followed.

Purpose of Cookery.—Much of our food has to be prepared for the table by a process of cooking. The aim of this art is to render food materials more easily digestible than they are in the raw and purely natural state, and to develop pleasing savors.* Any operation in cookery which fails to accomplish both of these ends, serves its purpose in-

* In their efforts to teach people that mastication and insalivation of food are important steps in the digestive process, physiologists have long declared that "digestion begins in the mouth;" now, however, this saying has with propriety been changed, and may be more properly rendered as "digestion should begin in the cook room."

completely. In its effects upon human kind the art of cookery exceeds the influence of the fine arts. The use of poorly cooked and insipid food has led many people to indulgence in spirituous liquors, whereby they hoped to stop the unsatisfied craving for a pleasing diet.

REVIEW.

1. Define food.
2. What would be the characteristics of a perfect and complete food?
3. Write a classification of foods.
4. Show the necessity of a variety of food materials.
5. What is your opinion as to the propriety of using meat for food?
6. Show the necessity of the food materials we eat being in a soluble condition.
7. Into what physical condition must all food stuffs be reduced before they can be absorbed and assimilated within the body?
8. Why should food be made pleasing to the senses?
9. Describe the notable experiments of the French scientists, Edwards and Balzac.
10. What is the object of cooking?
11. What bad effects may follow the effect of poorly cooked and unsavory food?

CHAPTER 26.

MINERAL INGREDIENTS OF FOOD.

Mineral Substances in the Body.—Certain mineral matters are indespensable to the growth of the body; the chief of these are water, common salt, and certain compounds of calcium, magnesium, iron, sodium, and potassium; also chlorine which is present in common salt; and sulphur, phosphorus, and silicon which are combined with the metals named above. Except water and salt, however, these mineral substances are absorbed within the body only when in combination with organic matters.

The phosphates of calcium, magnesium, and potassium are needed for the formation of bone, muscle, brain and nervous tissue; iron is an essential ingredient of the red corpuscles of the blood; the alkalies, potash and soda, are required for the blood and for many of the solid tissues; salt is needed throughout the system, and water composes from two-thirds to three-fourths of the whole bodily weight. The importance of the mineral ingredients of food is therefore clear.

Water has already received a somewhat extensive treatment, an entire section of this little book having been devoted to its consideration. A mere mention at this point must therefore suffice. The table on page 179 shows the proportions of the liquid present in

different tissues of the body. Water is a universal carrier. No solid matter is absorbed in the bodies of men, animals, or plants except in solution.

Common Salt exists as an essential constituent of all solids and fluids of the human body. In the blood, salt is present in greater quantity than any other mineral ingredient, except water. Dalton gives the following proportions of salt present in certain tissues and products of the human body; the figures state the parts of the solid present in a thousand parts of the substances named:

	Common salt present in 1000 parts.
Muscle	2. parts
Bone	2.5 "
Cartilage	2.8 "
Milk	1. "
Saliva	1.5 "
Bile	3.5 "
Blood	4.5 "
Mucus	6. "

Salt is present as a natural constituent in many articles of diet; but to supply the requisite quantity it is added to the food as a condiment. Moderation in its use, however, is essential to health. It is possible to acquire a disordered appetite through the lavish use of salt; the craving for condiments once started within the body is liable to grow till it becomes a serious habit. Salt excites the nerves of taste, and renders pleasing food that otherwise would be insipid and tasteless. In the absence of salt, food could be but imperfectly digested, and a long continued deprivation of this substance would seriously affect the bodily powers, and would lay the system open to the

inroads of disease. In Holland there was once a law, that for certain grave offenses, prisoners should be fed on food entirely free from salt; this was regarded as the severest punishment that could be inflicted. Few sufferers long survived treatment of this kind; their craving for salt grew so intense as to induce insanity; and their bodies became fatally disordered. Salt is no less essential to animals than to the human being. Without salt our domestic animals become dull and diseased; their skins grow rough, and much of the hair falls. Stock-keepers know from experience the value of providing their animals with a free supply of salt. Wild beasts whose wariness secures them against being entrapped by tempting baits of food, are readily captured at natural or artificially prepared "salt licks." In some parts of the world, where salt is scarce, the article commands a very high price.*

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*"In man, the desire for salt is so great that in regions where it is scarce it is used as money. In some parts of Africa a small quantity of salt will buy a slave, and to say that a man commonly uses salt at his meals is equivalent to stating that he is a luxurious millionaire. In British India, where the poorer natives regard so few things as necessaries of life that it is hard to levy any excise tax, a large part of the revenue is derived from a salt tax, salt being something which even the poorest will buy. As regards Europe, it has been found that youths in the Austrian Empire who have fled to the mountains, and there led a wild life to avoid the hated military conscription, will, after a time, though able abundantly to supply themselves with other food by hunting, come down to the villages to purchase salt, at the risk o liberty, and even of life."—DR. NEWELL MARTIN.

"Animals will travel long distances to obtain salt. Men will barter gold for it; indeed among the Gallas and on the coast of Sierra Leone, brothers will sell their sisters, husbands their wives, and parents their children for salt. In the district of Accra, on the gold coast of Africa, a handful of salt is the most valuable

Natural Occurrences of Salt.—Yet the natural sources of salt are apparently inexhaustible. Vast deposits of it occur in the earth, and streams of water flowing to the sea carry the substance in solution to their ocean bed. Sea water contains on an average three per cent. of salt; the waters of the Great Salt Lake contain about eighteen per cent. of their weight of salt. Some varieties of commercial salt are very impure, containing considerable quantities of magnesium and lime in combination. Utah possesses natural salt in apparently unlimited quantities; vast deposits of rock salt occur throughout Sanpete and Sevier Counties, and so in other parts; and the waters of Salt Lake could supply the world with salt for a long period.

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thing on earth after gold, and will purchase a slave or two. Mungo Park tells us that with the Mandingoes and Bambaras the use of salt is such a luxury that to say of a man 'he flavors his food with salt,' is to imply that he is rich; and children will suck a piece of rock salt as if it were sugar. No stronger mark of respect or affection can be shown in Muscovy than the sending of salt from the tables of the rich to their poorer friends. In the book of Leviticus it is expressly commanded as one of the ordinances of Moses, that every oblation of meat upon the altar shall be seasoned with salt, without lacking, and hence it is called the Salt of the Covenant of God. The Greeks and Romans also used salt in their sacrificial cakes; and it is still used in the services of the Latin church—the '*parva mica*,' or pinch of salt, being, in the ceremony of baptism, put into the child's mouth, while the priest says, 'Receive the salt of wisdom, and may it be a propitiation to thee for eternal life.' Everywhere. and almost always, indeed, it has been regarded as emblematical of wisdom, wit, and immortality. To taste a man's salt was to be bound by the rites of hospitality; and no oath was more solemn than that which was sworn upon bread and salt. To sprinkle the meat with salt was to drive away the devil, and to this day, nothing is more unlucky than to spill the salt."—LETHERBY.

Lime is the most abundant of the solid inorganic ingredients of the human body. It is present in all tissues and liquids of the system though in widely varying quantities. It occurs mostly as calcium phosphate, and less abundantly as calcium carbonate. According to Dalton, the following figures show the quantity of calcium phosphate in 1000 parts of the tissues and fluids named:

	Lime phosphate in 1000 parts.
Teeth	650
Bones	550
Cartilages	40
Muscles	2.5
Blood	0.3
Gastric juice	0.4

The hardest substance of the body is the enamel of the teeth; this consists mostly of lime salts, the phosphate being in excess. Lime imparts strength and rigidity to the bony skeleton; a deficiency of it causes pliancy and disease of the bones. In early life, the bones are naturally soft, because, ossification being then incomplete, the animal matters of the bones exceed in quantity the mineral substances; children, therefore, require a comparatively large amount of lime salts; and this is best supplied through means of a generous diet of milk and grain preparations, with a very moderate allowance of animal food other than milk.

A common and an instructive demonstration of the importance of lime compounds in the bones, may be made by soaking a bone in dilute acid, thereby removing the mineral substances. Procure a rib for the

purpose: it being in shape long and slender will be well adapted. Place the bone in a mixture of one part muriatic acid and fifteen parts water; allow it to remain in the acid during a few days, then remove and wash it. The bone will be found soft and pliable, so that it may be easily bent in any desired form, or even tied in a knot as illustrated in figure 88. The animal tissue that remains after the treatment with acid will dry and become hard and transparent.

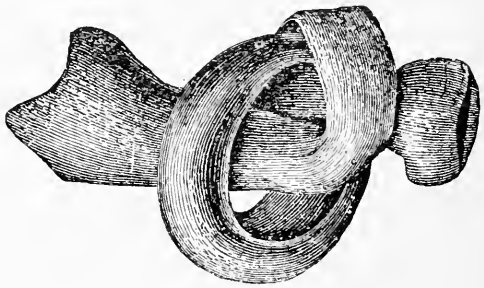

Fig. 88.
Bone, after treatment with acid, tied in a knot.

Iron constitutes about one-thousandth part of the weight of the blood; it is essential to the red color of the blood corpuscles. In the entire body there is about five drachms of iron. When the blood is deficient in this element, it becomes pale in color, the skin assumes an unnatural pallor, and the bodily strength very rapidly diminishes. It is then a common practice in medicine to administer iron in a soluble form, usually as the tincture of iron per-chloride, or as iron citrate. Iron is supplied in the food through the medium of milk and eggs, and many vegetable articles of diet.

Sulphur and Phosphorus, though present in very small quantities, are still essential within the body. These substances occur mostly in combination, as phosphates and sulphates of calcium, magnesium, potassium, and sodium. Dr. Foster says: "The element phosphorus seems no less important from a biological point of view than carbon or nitrogen. It is as absolutely essential for the growth of a lowly being like penicillium* as for man himself. We find it peculiarly associated with the proteids, apparently in the form of phosphates, but we cannot explain its *role*. The element sulphur, again, is only second to phosphorus, and we find it as a constituent of nearly all proteids, but we cannot tell exactly what would happen to the economy if all the sulphur of the food were withdrawn."

The compounds of *magnesium*, *potassium*, *sodium*, and *silicon*, which are called for in much smaller quantity than are the substances already named, are present in ordinary food stuffs, and are seldom found in insufficient quantity within the body.

Mineral Ingredients of Food Within the Body.—The mineral elements of food as a rule do not undergo chemical change by decomposition or combination within the body. They are absorbed with the food and enter the tissues, forming an indispensable part of the body substance; then they are removed by the processes of secretion, and their place supplied by

* *Penicillium*—the common green mold or mildew, so common in damp situations, as upon old shoes, bread, vegetables, fruits, and jams. It is a living thing; a plant belonging the order of *fungi*.

other particles of the same kind. The changes produced upon mineral matters by the processes of cooking are so light as to be inconsiderable for our present purpose.

REVIEW.

1. Name the principal mineral matters indispensable to the bodily growth.
2. Show the occurrence of mineral matters in the different parts of the body.
3. Show that water is an essential ingredient of living bodies.
4. Show the occurrence of salt within the human body.
5. Give instances of the ill effects of depriving the body of salt.
6. Relate some of the instances quoted to illustrate man's craving for salt.
7. What do you know of the natural occurrence of salt in Utah?
8. Show the occurrence of lime within the human body.
9. Describe a demonstration of the value of lime as an ingredient of the bones.
10. What do you know of the occurrence of iron in the body?
11. Discuss the value of the compounds of sulphur within the body.
12. Of phosphorus compounds.
13. Of magnesium compounds.
14. Of potassium compounds.
15. Of sodium compounds.
16. Of silicon compounds.

CHAPTER 27.

ORGANIC INGREDIENTS OF FOOD; CARBONACEOUS FOODS: STARCH, SUGAR, GUM.

Organic Food Matters.—Certain food materials occur in Nature as products of animal or vegetable life only; such are called organic foods, to distinguish them from mineral matters. The organic ingredients of food may be classified as shown on page 254.

Carbonaceous Food Substances; Amyloids;—These claim our attention first; they are so named because of the predominance of carbon as an element of their composition. The amyloids, such as the starches and the sugars, consist entirely of carbon, hydrogen, and oxygen; they are therefore known chemically as carbohydrates. The fats contain the same elements, though in different proportions, oxygen being present in them in very small quantity. The amyloid group of food substances includes starch, sugar, and gum, of each of which there are many varieties.

Starch in its prepared form appears as a white powder, possessing a gritty feel if rubbed between the fingers. When viewed through the microscope the powder will be seen to consist of minute rounded grains, the exact form varying in starches from different sources. Figure 89 represents starch granules

from the potato; these particles are somewhat like clam shells, the surface of each being marked by waving lines concentric about a point known as the *hilum*, which point marks the place at which the grain was originally attached to the cell wall. Grains of potato starch vary in size from $^1/_{10000}$ to $^1/_{300}$ of an inch in diameter.

Fig. 89.
Potato starch granules; (magnified)

The grains of wheat starch are represented in figure 90; these are smaller than the preceding; they rarely exceed $^1/_{700}$ inch in diameter, and from that they vary to $^1/_{10000}$. Starch granules from wheat present a circular outline; though many of the grains are flattened, so that in a side view they present a narrow edge. Starch from oats consists of large, compound granules, which under pressure may be readily broken into sections. Starch grains from maize, or Indian corn, and the grains of rice starch are irregular in form, many of them presenting an angular outline.

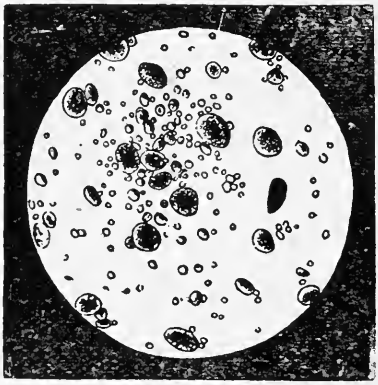

Fig. 90.
Wheat starch; (magnified)

Starch in Plants.—Starch is of common occurrence in plants. At certain seasons the substance accumulates within the body of the plant in great quantity; starch is the form in which the plant stores its food material for future growth.* Its wide occurrence is shown by the following table:

	Average percentage of starch.
Potatoes	15.70
Peas	32.45
White beans	33.00
Kidney beans	35.94
Buckwheat	52.00
Rye flour	56.00
Oatmeal	59.00
Wheat kernel	59.5
Rye meal	61.07
Barley meal	67.18
Wheat flour	72.00
Maize	80.92
Rice	85.07

Certain articles of diet consist almost entirely of starch, such are corn-starch, arrowroot, sago, tapioca and rice; these will receive our future attention. For the present let us examine the living plant and inform ourselves of the way in which starch is stored within it. The microscope has revealed the important fact that all plant tissue consists of thin-walled inclosures known as *cells*, and within these the secretions peculiar to the plant are formed. Figure 91 shows three sec-

*The food material being stored within the plant in the form of starch, and starch being insoluble in cold water, the plant stores are safe from loss by rains or floods. This insoluble starch is changed to a soluble sugar as fast as the plant requires the material for its own growth.

tions of plant tissue containing starch granules; the upper left hand sketch illustrates a potato cell; the other upper section is that of an oat seed, and the lower one represents a wheat kernel.

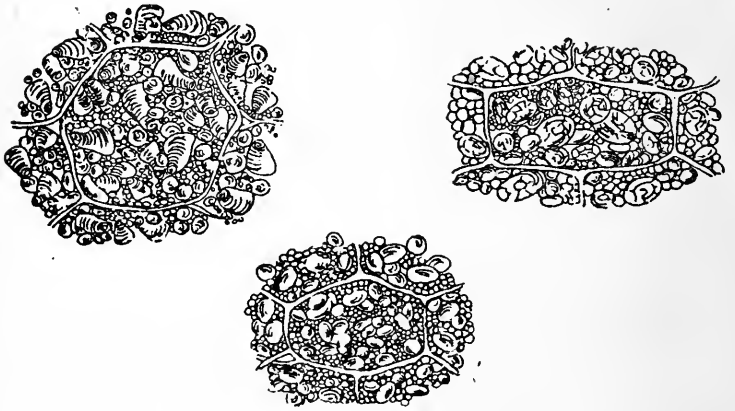

Fig. 91.
Plant cells filled with starch.

Starch is scarcely soluble at all in cold water; but, when heated in water near the boiling point, the grains absorb liquid, and burst, forming a jelly or paste. In this form, starch is of use for laundry purposes; this "boiled starch" is not a true solution, however; the starch and water may be almost entirely separated by freezing. The fact that cold water has so little solvent effect on starch, suggests a method for its preparation.

Grate some potatoes to the condition of a fine pulp; place this within a bag of coarse muslin; immerse in water and knead well under the liquid. The water

soon becomes milky, and after a time a white powder settles to the bottom. This is starch; it may be removed from the water and dried. Wheat flour may be treated in the same way and starch procured from it.

Sugar is a sweet vegetable product, found in the juice of cane, the roots of beets, the sap of certain trees, and in many fruits. In a chemical sense there are many kinds of sugar, the chief of which are saccharose or cane sugar, glucose or grape sugar, levulose or the sugar of fruit, and lactose or sugar of milk.

Saccharose is found in a fairly pure form, as loaf and granulated sugar of commerce, though a still purer kind is met with in the uncolored and crystallized rock-candy. This is the most sweetening of all common sugars. It is prepared chiefly from the sugar cane, sugar beet, and sugar maple. It may also be produced from sorghum, and in smaller quantity from the juices of many other plants, as maize, parsnips, carrots, etc. The following table shows the proportions of sugar present in different products:

	Per cent. of sugar.
Indian corn	1.5
Peas	2.
Ryemeal	3.2
Oatmeal	4.8
Barley meal	5.2
Wheat flour	5.4
Beets	9.0
Ripe pears	11.5
Ripe peaches	16.5
Ripe cherries	18.1
Figs	62.

Saccharose melts at about 356° F., and if cooled rapidly from that temperature it forms a granular mass known as barley sugar; of this the prepared candies largely consist. If a higher heat be applied to sugar it becomes burnt or caramelized. Caramel is used as a coloring agent in cooking.

The Preparation of Saccharose from vegetable liquids is an instructive process. The juice is obtained by pressure; it is then mixed with a quantity of lime to neutralize any free acid present and to assist in settling the impurities; the clarified juice is then evaporated, and the product is crude, brown sugar, commonly known as *Muscovado* sugar. This is to be purified. It is dissolved in water and the solution is decolorized by being heated with bone black or animal charcoal. It is then clarified by an addition of albumen, usually in the form of blood; this by its coagulation and settling carries most of the impurities to the bottom. The liquid is then evaporated, and the crystalizing sugar is separated by centrifugal power. To prevent burning of the sugar, the evaporation is conducted in vacuum pans, which are vessels so constructed as to cause the removal of the vapor as fast as formed; by these means the pressure upon the liquid is reduced and the boiling proceeds at a much lower temperature. The purified article appears as loaf or granulated sugar.

The syrup remaining after the crystallization, is known as molasses, sometimes called treacle, though much molasses is made from sorghum juices without any separation of sugar. The difficulties thus far ex-

perienced in the preparation of sugar from sorghum have been largely due to the ready inversion of the contained saccharose, by which it becomes changed into glucose and levulose. These obstacles have been mostly overcome during recent years, and a very good article of sugar is now obtainable from sorghum cane.

Glucose or grape sugar occurs in many fruits, being specially plentiful in grapes. This sugar does not readily crystallize, and its sweetening power is not more than three-fifths that of cane sugar. It may be prepared from starch by simple processes. Several large establishments in the United States are devoted entirely to the manufacture of glucose from Indian corn. As a result of extended tests it is believed that glucose is no more unwholesome as an article of food than is true cane sugar, though doubtlessly extensive frauds are in operation by which saccharose is largely adulterated with the cheaper glucose. The transformation of starch into glucose takes place in the sprouting of seeds; plants store their food supplies within the seeds as insoluble starch; when germination begins the starch becomes glucose, and is easily absorbed and assimilated by the growing plant. It is an easy matter also by chemical means to transform saccharose into a mixture of glucose and levulose; but thus far no satisfactory method of making the reverse transformation, namely, from glucose to the sweeter saccharose, has been devised.

Vegetable Gums are by no means inconsiderable as elements of food, though in this country they are

seldom used in special food preparations. The principal gums that enter into the composition of food stuffs are arabin or gum arabic, cerasin or the gum from cherries and plums, and vegetable mucilage which occurs in almost all kinds of plants. Gum is present in considerable quantity in grains and in preparations from them. The following table, according to Von Bibra, shows the proportion of gum in several dry plant products:

	Per cent. of gum.
Wheat kernel	4.50
Wheat flour	6.25
Wheat bran	8.25
Rye kernel	4.10
Rye flour	7.25
Rye bran	10.40
Barley flour	6.33
Barley bran	6.88
Oatmeal	3.50
Rice flour	2.00
Millet flour	10.60
Maize meal	3.05
Buckwheat flour	2.85

Dextrin.—By heating starch to a temperature of 300° F. it undergoes a remarkable change, assuming a yellow color and becoming readily soluble in water. This substance is a kind of gum, and has been named dextrin. It is largely used as a dilutent for other gums, and in a prepared state as a mucilage is sold as British gum, Alsace gum, and starch gum. It has strong adhesive properties.

REVIEW.

1. What is an organic food?
2. Give a general classification of organic foods.
3. What are the distinguishing characteristics of carbonaceous food substances?
4. Name the chief members of the amyloid group of food substances.
5. Describe the microscopic appearance of potato starch.
6. Of starch from other plants.
7. Show the abundance of starch in certain plants.
8. Describe the occurrence of starch within the plant cells.
9. What do you know of the action of cold and hot water on starch?
10. How would you prepare starch from potatoes?
11. Name the principal sugars, giving the chief sources of each.
12. Show the occurrence of sugar in plants.
13. What do you know of saccharose?
14. Of glucose?
15. Of levulose?
16. Describe briefly the processes of sugar refining.
17. What do you know of vegetable gums as food articles?
18. Show the occurrence of gum in plants.
19. What do you know of dextrin, its preparation, properties, and uses?

CHAPTER 28.

CARBONACEOUS INGREDIENTS OF FOOD, CONTINUED. VEGETABLE ACIDS AND FATS.

In composition, the **Vegetable Acids** are closely allied to the sugars and starches already considered. The name vegetable acids expresses at once the nature and occurrence of the substances; they give sourness to fruits and many vegetable products, though they are present in plants in very small proportion only. In food they serve to impart a pleasant, pungent taste, and within the body, they undergo ultimate digestion as do the starches and the sugars.* The chief of the vegetable acids are citric acid, tartaric acid, malic acid, and oxalic acid.

Citric Acid is the sour principle of lemons; it occurs also in oranges, citrons, cranberries, and unripe

*The following appears (quoted) in the "Scientific American," Aug. 20th, 1892. "We know that many vegetable and fruit products are esteemed rather for their pleasant or refreshing taste and for their anti-scorbutic properties, than for any nutritive value which they may be assumed to possess. Yet even fruits of that character are especially valuable as additions to our daily diet, on account of the potash salts and mild vegetable acids they contribute to the blood. * * * Many persons know from experience how much more pleasant and agreeable fruit is when gathered and eaten direct from the tree. This is undoubtedly in part due to the freshness and briskness of the vegetable acids contained in the fruit, which when so gathered and eaten have not time to change into any other substance. Stale fruit, on the other hand, is unpalatable from the very fact that it has lost this pungent and brisk taste."

tomatoes; associated with other acids it is found in strawberries, raspberries, currants, gooseberries, and cherries; and in smaller quantity, combined with lime as calcium citrate, it is found in artichokes, onions, and beets. Citric acid is an ingredient of many common sour and effervescent beverages.

Tartaric Acid is the prevailing acid of grapes; it is found, too, in many other fruits; and in the combined state as tartrates of potassium and calcium, it is also found in potatoes, pine apples, cucumbers, and in sumach berries. The chief source of the acid is argol or crude potassium tartrate, which collects as sediment in vats of fermenting grape juice. Purified potassium tartrate is known as cream of tartar. In a pure state tartaric acid crystallizes in clear large plates; it is intensely sour to the taste, and is used in preparing effervescing drinks. For such purposes, however, it is but an inferior substitute for citric acid.

Malic Acid is the chief cause of sourness in apples, pears, small fruits, plums, peaches, and cherries. It is widely distributed throughout the vegetable kingdom, especially in immature fruits. In combination with potassium it is abundant in the juices of rhubarb. The acid is seldom prepared in a pure state, as but little practical use has been found for it; it may however be purified as a white crystalline solid very readily soluble in water, the solution possessing an intensely sour taste.

Oxalic Acid exists in sorrel, rhubarb, and many other plants. It is usually found in combination with calcium and potassium as oxalates of those metals.

Potassium oxalate has long been sold as "salts of sorrel," and has found domestic application as a means of removing ink stains and iron-mold spots from clothes. Purified oxalic acid appears as transparent crystals; it is intensely poisonous, and many fatalities have resulted from its use. It has many times been mistaken for Epsom salts, which indeed it greatly resembles in outward appearance.

Pectin or Vegetable Jelly is very closely akin to the vegetable acids just considered. This is largely prepared from fruits by heating them with water, sweetening and straining. The solution becomes a jelly in cooling. The acids present in jelly so prepared are known as pectic and pectosic acids. These by long continued heating become transformed into metapectic acid which is so readily soluble that a solution containing it no longer solidifies on cooling. This is well known to housewives who have tried to concentrate a fruit jelly by long continued heating; usually a syrupy liquid only is obtained. It is a general belief that sugar is essential to the production of a jelly from vegetable juices; the sugar, beside its sweetening effect, absorbs the excess of water present, and leaves the pectic and pectosic acids free to soldify by cooling.

Acetic Acid is of vegetable origin, though not occurring free in Nature; it is the sour substance in vinegar. This will receive brief attention in the chapter on "Auxiliary foods."

Vegetable Acids Transformable into Amyloids.—It has already been stated that the vegetable

acids are allied in chemical nature to the amyloids already described. Examples of the transformation of acids into starch and sugar are common in Nature. Thus, in the green state, apples are intensely sour; as the ripening process proceeds, however, the sourness is less marked, and a chemical examination shows an increase in sugar, and a corresponding diminution of malic acid and starch.

Fats and Oils constitute the next group of carbonaceous food elements. These substances consist of carbon, hydrogen, and oxygen, the last named element however, being present in very small proportion only. The fats are therefore spoken of as hydro-carbons. Some fats both of animal and of vegetable origin, are characterized by containing a small amount of phosphorus; these are known as phosphorized fats. The oil from peas contains 1.17 per cent. phosphorus; bean oil .72 per cent.; vetch oil .5 per cent.; barley oil .28; rye oil .31; oat oil .44.*

Relation between Fats and Oils.—There appears no essential difference of composition between the solid fats, and the liquid oils, the consistency depending greatly upon the temperature. Tallow may be reduced by warming to a mobile liquid; and olive oil may be solidified by cold. In Africa, the fat of the palm tree is in the state of liquid palm-oil; with us the same substance is semi-solid and is known as palm-butter.

Oils, Fixed and Essential.—Of common oils

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*These figures are given on the strength of Toepler's experiments.

there are two main groups, the fixed oils, and the volatile or essential oils. The former are the more important as food elements; they may be recognized by their power of producing permanent grease stains when placed upon paper; even gentle warming fails to remove such spots. A volatile oil if smeared on paper, produces but temporary stains: these entirely disappear by heating. Some volatile oils do slight service as auxilliary foods; but for the present we confine ourselves to a consideration of fixed oils and fats only as they constitute our main source of this class of foods.

Vegetable Fats are largely obtained from seeds; good examples are furnished by the oily seeds of flax, colza, cotton, peanut, butternut, and sunflower. The following specification shows the amount of oil present in certain vegetable products:

	Per cent. of oil.
Meadow grass	0.8
Meadow hay	3.0
Clover hay	3.2
Wheat bran	1.5
Wheat kernel	1.6
Wheat flour	1.5
Maize kernel	8.0
Pea	3.0
Rice	0.8
Buckwheat	0.4
Olives	32.0
Cotton seed	34.0
Flax seed	34.0
Colza seed	45.0
Cocoanuts	47.0
Filberts	60.0

There is a strong prejudice, none the better because popular, against the use of vegetable oils in food.

As a rule we prefer the poorest of lard, to the purest oils of olive and palm; yet as cooking media the plant oils are in all respects superior. Cotton-seed oil has been proved to be nutritious and wholesome; it has lately found extensive use in the preserving of fish, and cotton planters now find the seed of their crop almost as valuable as the fibre. True, the price of refined vegetable oil is at present high when compared with the cost of animal fats; the crude oil, however, is far cheaper than the unrefined animal product, and as soon as a demand arises for pure vegetable oils, there will be no lack of supply at a cheap rate.

Animal Fats.—Fat is also present in common articles of animal food, as these figures will show:

	Per cent of fat.
Cows' milk	3.13
Goats' "	3.32
Ordinary meat	14.03
Liver of ox	3.89
Yolk of eggs	28.75

Common Fats.—The principal common fats are enumerated and briefly described below:

Olein is abundant in ordinary oils; being the most fluid of common fats, it may be prepared in quantity from oils and the softer fats.

Palmitin is plentiful in African palm oil; it occurs also in beeswax and tallow. It is fluid only during warm weather, or under the influence of artificial heat.

Stearine may be prepared from tallow. It is pres-

ent in all common fats, and being solid at ordinary temperatures imparts solidity to other fats.

Some Properties of Fats.—Fatty substances are generally insoluble in water; yet under certain conditions, oils may be suspended in water in a very finely divided state; such a mixture is known as an emulsion. A little oil shaken up in water to which a minute quantity of soda had been added, will exemplify an emulsion. The microscope shows in such a mixture the oil drops still separate and perfect. Milk is an example of a natural emulsion. A farther characteristic of all fats is their property of forming soaps with the alkalies.

Fats constitute a very important part of food material. When eaten, fatty matters develop great bodily warmth, they are therefore well adapted as a diet for cold climes. Under the influence of severe cold, a strong, natural craving for fat is developed. Seamen, wintering in Arctic regions, eat fats with relish. The Esquimaux in their wintry home devour immense quantities of oleaginous matter.*

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*Dr. Hutchinson says, "The Esquimau consumes daily from ten to fifteen pounds of meat or blubber, a large proportion of which is fat. The Laplander will drink train oil, and regards tallow candles as a great luxury."

The need of fat in the food of children is very great. Dr. Edward Smith says on this subject, "Children who dislike fat cause much anxiety to parents, for they are almost always thin, and if not diseased, are not healthy. If care be not taken they fall into a scrofulous condition, in which diseased joints, enlarged glands, sore eyes, and even consumption occur; and every effort should be made to overcome this dislike. If attention be given to this matter of diet, there need be no anxiety about the possibility of increasing the quantity of food consumed; whilst by neglect,

REVIEW.

1. Name the principal vegetable acids occurring in food stuffs.
2. State what you know of citric acid.
3. Of tartaric acid.
4. Of malic acid.
5. Of oxalic acid.
6. Describe the occurrence and properties of pectin.
7. Why is it that a fruit jelly by continued heating becomes permanently liquid?
8. What is the general composition of fats?
9. With what classes of oils are you acquainted?
10. How may we distinguish between fixed oils and volatile oils?
11. Show the occurrence of fats and oils in plants.
12. Name some of the principal vegetable oils.
13. What do you know of olein, palmitin, stearin?
14. What is an emulsion?
15. Show the value of fats as food.

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the dislike will probably increase until disease is produced. The chief period of growth, viz.—from seven to sixteen years of age—is the most important in this respect, for a store of fat in the body is then essential. Those who are inclined to be fat, usually like fat in food, and then it may be desirable to limit its use. Some who cannot eat it when hot like it when cold, and all should select that kind which they prefer."

CHAPTER 29.

NITROGENOUS INGREDIENTS OF FOOD.

Nitrogenous Food Necessary.—Nitrogen is an essential constituent of most tissues of the human body; there is need, therefore, of nitrogenous food to nourish the parts. The importance of foods of this nature is so great that they have been called flesh formers. We must not be led by this appellation to the extreme belief that no food material devoid of nitrogen is of value; starches and sugars, gums and fats, are of indispensable service in sustaining bodily heat, and they serve also as sources of actual energy, which manifests itself as muscular force. It is a plain fact nevertheless, that non-nitrogenous matter can but imperfectly build up tissues of which nitrogen forms an important constituent.

From the general resemblance of all nitrogenous food compounds to albumen, the first and commonest of the group, they are often called albuminoids, sometimes also proteids: this last name is derived from the Greek and signifies "first" or "most important," having reference here to the imperative need of nitrogenous substances within the body. The albuminoids are composed of nitrogen, carbon, hydrogen and oxygen; many of them contain also a small proportion of sulphur.

Albumen may properly be studied as the first of

the group; it is found in an almost pure condition, except for an admixture with water, in the white of egg. The word "albumen" is of Latin derivation, from *albus*, meaning white, and is so applied because of the white color assumed by the substance when heated. A careful study of the properties of albumen is essential to an understanding of many operations in cooking. Procure a fresh egg, separate the yolk from the white, and place the latter in a glass test tube, insert a thermometer, and immerse the lower part of the tube in water which is being gradually heated. As the temperature within the tube ranges from 130° to 140° F., white, opaque fibers appear in the substance; these increase till the whole mass of albumen has been converted into a white, semi-solid coagulum. This change will be complete when the temperature has risen to 170° F., and any greater heat will harden the egg substance, and if long continued will convert it into a tough, apparently indigestible mass. It is plain then that a temperature of 170° F. is sufficient to properly coagulate the albumen.

In the liquid condition, albumen is soluble in water; after coagulation, however, it is almost entirely insoluble. As an illustration of this, the white of egg may be shaken or stirred in cold water, and completely dissolved therein; on heating the liquid to the proper temperature the albumen will appear in the solid form as flakes. Albumen as a food is mainly derived from the animal kingdom, though the substance exists in the juices of plants, and in many seeds and grains.

Fibrin, another albuminoid, is present in considerable quantity in many animal fluids. The clotting of blood is due to the spontaneous coagulation of the contained fibrin. To procure fibrin for examination, place a quantity of fresh blood in an open vessel, agitate or whip the liquid with a wisp of fine twigs or wires; the fibrin will gather upon the bundle in the

Fig. 92.
Fibers of lean meat.

form of stringy, semi-liquid masses. Blood so defibrinated has lost its power of clotting.* The separated

* Exposure to the air induces the clotting of blood. This change is caused by the hardening of the fibrin—a constituent of the plasma—by which the blood corpuscles are entangled so as to form a plug or clot. A yellowish liquid separates as the clot forms; this is known as blood-serum. The benefits resulting from this property of blood can scarcely be over-estimated. In the case of a severed vein or artery, the flow is checked by clotting, while the healing of the vessel is in progress. Did this property not exist in the blood, bleeding could be stopped only by artificial means. Among birds the clotting of blood is especially rapid. This feature is a great benefit to these winged creatures, for the great muscular exertion of flying would cause profuse bleeding from very small wounds, were it not for the stopping of the injured vessels by the blood clots. In this we see divine provision even for the accidents to which animals and men are subject.

fibrin may be washed and purified; then it appears of a yellowish color, and is soluble in hot water.

Take now a bit of raw lean meat, thoroughly wash it in water; the liquid becomes colored from the red juices taken from the meat, and that which remains is of a purplish tint and of a fibrous structure. These fibers consist mainly of animal fibrin, though the distinguishing name of myosin has been applied to such. Figure 92 is a sketch of the magnified fibers of lean meat.

Fibrin is also present in certain plants, especially in juices. If turnip juice be exposed to the air, after a short time it deposits solid flakes of coagulated fibrin. For purposes of distinction this has been named vegetable fibrin.

Gelatin is a very important member of the albuminoid family of foods. It is present in most of the tissues of the animal body, including bones and cartilage. In a purified form gelatin is insoluble in cold water, though it dissolves readily in hot water, and the solution on cooling assumes the condition of a jelly. Gelatin is the chief ingredient of all animal jellies. One ounce of pure gelatin is capable of combining with one and a half pounds of water to form jelly. The purest commercial form of gelatin is isinglass, which is a preparation from the swimming bladders of fishes. Specimens of gelatin from different sources possess widely varying degrees of solubility. Calves' foot jelly is a delicious food; jelly made from the feet of cows is less prized because of its inferior solubility. The turtle's body is rich in gelatin, and

as a consequence it is in great favor as a prime ingredient of soup; a somewhat inferior and much less expensive luxury is mock turtle soup, which contains gelatin from pigs' feet, calves' heads, and the like.

The material of which the *edible birds' nests* are composed is a kind of gelatin. These nests are constructed by a species of swift* inhabiting the coasts of China, Sumatra, and Java. The birds produce large quantities of slimy saliva, which, on drying, becomes solid and transparent gelatin; it is readily soluble in hot water, the solution constituting the much-prized jelly.

The Value of Gelatin as Food has been made the subject of special inquiry by certain members of the French Academy, as already stated (page 258). M. Edwards, one of the experimenters, draws the following conclusions from his observations and tests.†

"1. That gelatin alone is insufficient for alimentation. 2. That although insufficient, it is not unwholesome. 3. That gelatin contributes to alimenta-

*This variety of swift, the "esculent swallow" as it is commonly called, delights to build in caves; and it is stated that a single cavern in Java, to which the birds have taken a decided liking as a place of abode, brings its proprietor an income of $25,000 a year rental, the sole value of the place depending upon the nests therein constructed. This cave the swifts share good naturedly with the bats, the latter holding possession during the day, and the birds occupying the lodgings at night. In shape the nests resemble hanging bags or pouches, and they are held firmly against the wall through the adhesive properties of the salivary mucus. Birds' nest soup ranks among the costliest of table delicacies of its class; the clean, dry nests sell in the market for their own weight in silver.

†The English construction is the translation of Mr. Mattieu Williams.

tion, and is sufficient to sustain it when it is mixed with a due proportion of other products which would themselves prove insufficient if given alone. 4. That gelatin extracted from bones, being identical with that extracted from other parts, and bones being richer in gelatin than other tissues, and able to afford two-thirds of their weight of it, there is an incontestible advantage in making them serve for nutrition in the form of soup, jellies, paste, etc.; always, however, taking care to provide a proper admixture of the other principles in which the gelatin soup is defective. 5. That to render gelatin soup equal in nutritive and digestible qualities to that prepared from meat alone, it is sufficient to mix one-fourth of meat soup with three-fourths of gelatin soup; and that, in fact, no difference is perceptible between soup thus prepared and that made solely from meat." We are then to regard gelatin as a very efficient food when properly flavored by admixture with other substances; alone it is repulsive to the system. Gelatin is furnished by the animal kingdom only.

Casein is the chief albuminoid of milk, in which it exists to the extent of from three to six per cent., and constitutes the greater part of the curd of milk. In fresh milk the casein is held in solution; by coagulation, however, as in cheese making, the substance is rendered almost entirely insoluble in water. The coagulation of casein in milk may be effected by adding a small quantity of acid; though the change is best brought about by the addition of rennet, which is an infusion of the mucous lining of a calf's stomach.

Unlike albumen, casein is not coagulable by heat. A common example of casein solidifying in the presence of an acid is seen in the spontaneous souring of milk; under particular circumstances the sugar in the milk is decomposed, lactic acid being formed in the process; this acid causes a speedy precipitation of the casein as a voluminous curd. When milk is curdled through the addition of rennet, the casein carries with it from solution many of the mineral salts, notably the phosphates, which were originally present in the milk; precipitation by acid, however, removes these substances from the curd, and they are lost in the whey. Cheese formed by the first method therefore is superior to that made by the addition of acid.

When separated from the other ingredients of milk and purified, casein appears as a yellowish, translucent solid, not unlike horn; in water this is ordinarily insoluble, but in weak alkaline solutions it readily dissolves. These facts will be of service to us in our subsequent examination of cheese as food.

Casein is found in small quantities in certain vegetables, especially in the leguminosæ—a family of plants including peas and beans. If such seeds be finely ground and then treated with water, the casein passes into solution, and may be precipitated as a coagulum by the addition of acid. Dried peas and beans will yield 20 per cent. of their weight of vegetable casein. The Chinese manufacture from peas a good article of vegetable cheese, which is almost indistinguishable by chemical means from milk cheese.

Gluten is a tough, elastic substance, present in

flour, and imparting to dough its property of stickiness. It may be prepared by kneading flour with water on a fine sieve, after the manner indicated by figure 93. The liquid soon becomes milky from the starch granules washed from the dough; the gluey mass remaining is a mixture of substances, containing considerable quantities of vegetable fibrin and of vegetable casein, and about 20 per cent. of pure gluten. In a dried state, gluten is a horn-like, semi-transparent solid, insoluble in cold water; slowly and but feebly soluble in hot water; readily soluble in acetic acid (strong vinegar) and in dilute alkalies.

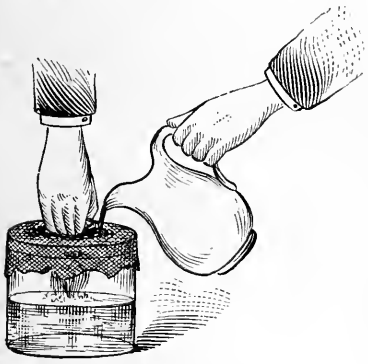

Fig. 93.
Separating the gluten of flour.

Properties of the Albuminoids.—Before leaving the albuminoids it will be well to consider some characteristics of the group. As already stated, they all contain a considerable quantity of nitrogen. Then further, they all possess the peculiar property of coagulation, though under different conditions; thus, heat coagulates albumen, acid or rennet is needed to curdle casein; blood fibrin coagulates spontaneously. All albuminoids are readily decomposable by heat, with evolution of an odor like that of burning horn. Under influences of moisture and warmth, albuminoids undergo a destructive change, known as putrefaction, in which process the albuminoid matter becomes partially liquified, and

gives off certain gases of disgusting odor. Albuminous matters have the power of acting as chemical ferments, so that if a small quantity of such in a decomposing state be placed with fresh material of the same kind, putrefactive changes are speedily excited throughout the whole mass. A bit of sour gluten introduced to dough soon "leavens the whole."

REVIEW.

1. What are albuminoids or proteids?
2. Define "albumen."
3. From what source would you procure albumen for study?
4. Explain the effect of heat on albumen.
5. What do you know of the temperature at which albumen coagulates and hardens?
6. State what you know of fibrin.
7. How would you obtain fibrin for study?
8. Explain the clotting of blood.
9. Show the great advantages to human and animal life resulting from the clotting of blood.
10. What is gelatin?
11. What do you know about edible birds' nests?
12. What is your opinion of the value of casein as an article of food?
13. Why is gelatine alone poorly adapted for food?
14. What is the prominent albuminoid in milk?
15. How may casein be separated from the other ingredients of milk?
16. Explain the souring of milk.
17. Why does milk curdle as it becomes sour?
18. What is rennet?
19. Why is cheese made by the use of rennet superior to cheese make by the use of acid?
20. What do you know of vegetable casein?
21. Describe the principal properties of gluten.
22. How would you prepare gluten for study?
23. State the principal characteristics of the albuminoid group of foods.

CHAPTER 30.

VEGETABLE FOODS AND THEIR COOKERY.

Having considered the chief ingredients of ordinary foods, it will be profitable now to devote some attention to the food stuffs that supply these substances. All of our common food materials are mixtures of several of the alimentary substances already referred to; it is common, therefore, to speak of ordinary foods as "compound aliments." Let us first consider the chief foods derived from the vegetable kingdom.

1.—TUBERS, BULBS, AND ROOTS.

Potatoes cannot properly be classed as roots; they have buds, (eyes), and rudimentary leaves (the little scales behind the buds), which no true roots possess; they are to be regarded as enlarged underground stems, to which the common name *tubers* has been applied. Potatoes are very extensively used as articles of food, though in chemical composition they are deficient in nutritive matters. On the average, potatoes contain from 76 to 80 per cent. of water; and of the remaining 20 or 24 per cent. dried matter, but a very small proportion is nitrogenous. In this respect the potato is even inferior to rice, which has long been regarded as one of the least nitrogenous of ordinary foods. Prof. Johnston's analysis show the following relative com-

position of potatoes and rice, only the dried substances being considered in either case:

	Potato per cen .	Rice per cent.
Gluten - -	5	9
Starch, sugar and gum -	81	89
Fat - - - -	1	0.5
Mineral salts - -	4	0.5

According to Smith, 2.5 pounds of potatoes are required to furnish the amount of carbon ordinarily contained in one pound of bread; and 3.3 pounds of potatoes contain no more nitrogen than is contained in a pound of bread. Williams states that a pound of oatmeal is worth 6 pounds of potatoes, as regards the contained nitrogenous matter.* A potato diet is at best a very poor one, and a person subjected to it has to devour immense quantities of the vegetable to obtain the nutriment requisite for the support of the body. However, potatoes serve an admirable purpose

* "My own observations in Ireland have convinced me of the wisdom of William Corbett's denunciation of the potato as a staple article of food. The bulk that has to be eaten, and is eaten, in order to sustain life, converts the potato eater into a mere assimilating machine during a large part of the day, and renders him unfit for any kind of mental or bodily exertion. .....The effect of potato feeding may be studied by watching the work of a potato-fed Irish mower or reaper, who comes across to work upon an English farm where the harvesters are fed in the farm house, and the supply of beer is not excessive. The improvement of his working power after two or three weeks of English feeding is comparable to that of a horse when fed upon corn, beans and hay, after feeding for a year on grass only. My strictures on the potato do not apply to them as used in England, where the prevailing vice of our ordinary diet is that it is too carnivorous. The potatoes we eat with our meat serve to dilute it, and supply the farinaceous element in which flesh is deficient."—W. MATTIEU WILLIAMS.

in diluting the fare of persons who are prone to excess in the use of over-stimulating and extra-nourishing food. The mineral substance or ash of potato tubers is very rich in potash, and contains a considerable proportion of other mineral compounds so essential in foods; but much of this valuable material is removed by the ordinary methods of cooking.

Cooking of Potatoes.—The practice of peeling potatoes, and then immersing them in water, results in the washing away of many of their mineral salts. A potato contains within itself sufficient water for its perfect cookery; and here we must pause long enough to inform ourselves of the chief differences between raw and cooked potatoes. Figure 91 upper left hand sketch, represents an enlarged view of a thin slice of potato tuber, showing the cells with their contents of starch granules; and figure 89 shows the starch particles separated and more highly magnified.

It will be remembered as a property of starch that the substance is insoluble in cold water; but that it may be made to absorb a considerable amount of hot water. In cooking a potato, its starch granules absorb water and burst; a single grain presenting some such an appearance as is shown in figure 94. As a result of heating prepared starch in water, a gelatinous mixture is produced; this condition is prevented in the case of the potato; because the starch grains within the tuber are protected

Fig. 94.
Bursting starch granule.

by stout cell walls, and the albumen of the potato coagulates through the heating process and thus still further protects the starch. The starch of mature potatoes, when heated, absorbs nearly all their contained water, and thus the tubers become dry and mealy; young potatoes, when heated, and indeed all kinds if cooked in a superabundance of water, become waxy, because a considerable amount of water remains unabsorbed. From the standpoint of economy and wholesomeness, the best methods of cooking potatoes are roasting and steaming; by either process the contained juices are raised to the cooking temperature, and are absorbed by the swelling starch particles. If "boiled"* at all, the least injurious way is to cook them with their skins still in place, leaving the peeling for a subsequent operation. In some parts of Ireland, the people depend largely upon potatoes for their support, and among them, experience has taught the ruinous waste of peeling potatoes before cooking.

Onions are thickened parts of the stems of plant, and are botanically called *bulbs*. The onion is rich in nitrogenous matter, and is correspondingly nutritious. Its strong odor is due to the presence of a peculiar

*It is a common but still a grossly improper practice to speak of things that have been kept for a time in boiling water, as being boiled. Only liquids can boil, and in boiling they are converted into vapor; thus water boils to steam; alcohol in boiling produces alcohol vapor; iron may be boiled, but it must first be melted to the liquid state, then, if sufficiently heated, the molten metal may be converted into vapor of iron. Potatoes cooked in water are not boiled, any more than is the iron of the cooking vessel boiled. The water boils, however, and the effect of the boiling temperature is to produce within the potato the desired changes of cookery.

sulphurized oil, commonly known as garlic oil. In Spain and Portugal, onions are used as staple articles of diet. As a result of chemical analysis, Johnston states that the onion contains from 25 to 30 per cent. of gluten.* Onions possess valuable medicinal properties, and the moderate use of the bulbs, either cooked or raw, is generally beneficial. On most people the physiological effect of onions is of a soothing kind, and in many instances the effects are decidedly soporific.

Turnips, Carrots, Parsnips, and Beets are true roots. They are rich accumulations of plant nutriment, being indeed the treasure vaults in which the growing plants have stored their gathered wealth, for use during the second year of their growth. These plants are biennials; during the first season they do not blossom at all; their energies are devoted to the absorption and storage of food material, which if the growth be uninterrupted, will be used by the plant during the next year's stages of flowering and seed bearing. Man avails himself of their labors by cultivating the plants till they have accumulated their wealth of food, which then he appropriates to his own use.

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* "It ranks," says he, "in this respect with the nutritious pea and the gram of the East. It is not merely as a relish, therefore, that the wayfaring Spaniard eats his onion with his humble crust of bread, as he sits by the refreshing spring; it is because experience has long proved, that, like the cheese of the English laborer, it helps to sustain his strength also, and adds—beyond what its bulk would suggest, to the amount of nourishment which his simple meal supplies."

All the roots named possess less dry substance than do potatoes, weight for weight; it will be remembered that potatoes contain on an average of 20 to 25 per cent. solid matter, while according to the figures of Dr. Youmans, turnips contain about 10.5 per cent. solid matter; yellow turnips 13.5 per cent., mangel wurtzel 15.5 per cent., carrots 14.22 per cent., beets 10.9 per cent., and parsnips 19.6 per cent. The nature of the solid contents, however, is such as to place the roots far above the potato as tissue-forming food. The nitrogenous ingredients of the dried mangel wurtzel amount to nearly twice as much as do those of the dried potato. Radishes are true roots; they are used mostly as salad, and as such are eaten raw. Their nutritive value is low.

In cooking, roots undergo changes analogous to those already described in the case of potatoes;—the contained starch granules absorb water, swell and burst; the albumen coagulates and the lignin or woody fibre, which is present in all vegetable tissues, becomes softened. If cooked in water, much of the mineral matter will be removed; steaming and roasting are far better processes. The skin should be undisturbed until after cooking.

2.—LEAVES AND LEAF STEMS.

These are less extensively used as articles of human food than are most other parts of plants. The nutritive qualities of leaves are shown by their composition, and by the fact that herbivorous animals, including

even those of gigantic bulk, derive their chief support from leaves.

Cabbage and Other Greens.—Cabbage is among the commonest of leaf foods used by man. The plant contains 90 per cent. water; the remaining 10 per cent. of solids is rich in nitrogenous matter, and contains a small proportion of sulphurized compounds. Cabbage, therefore, supplies the ingredients in which potatoes are deficient, and the union of the two vegetables is a good one, and with the addition of a little fat, makes a mixture that is generally nutritive.

Spinach, dandelion leaves, nettle tops, turnip leaves, and the fleshy stems of asparagus are often used as "greens." They are all nutritive and valuable foods.

Salads.—Lettuce, water cress, garden cress, young mustard plants and celery, furnish leaves and leaf-stalks for food, and such are largely used in the raw state as salads. Lettuce contains a milky juice which is possessed of narcotic properties. From the juice of the native plant lactucarium is prepared; this is used in medicine as a substitute for opium. The use of salads as food is productive of good from the fact that raw plants, when eaten, supply the body with an abundance of mineral salts; these ingredients are frequently lacking in cooked vegetables. The Welsh peasant, and the Swiss mountaineer would be unable to preserve health on their ordinary diet of cheese and bread, but for the addition of raw salads in abundance. In this connection it should be known that there are many valuable sources of food growing wild about our houses; but these we are apt to call weeds, and to treat

them with disdain. Comparing customs of different peoples we find a very wide range of salad plants in constant use.*

3.—FRUITS.

Fruits are common articles of food. Most of them are of a pulpy consistency, and contain a large proportion of water, with varying amounts of sugar, vegetable acids and pectin or vegetable jelly; there are also present peculiar aromatic substances which give to fruits their characteristic flavors. We know comparatively little of the exact composition of fruits. Experience has proved them to be pleasing and wholesome, and in moderate amounts they may profitably be introduced in any ordinary dietary. Fruits may be eaten raw or in a preserved form; most kinds may also be dried and kept without decomposition for long periods. Dried fruits should be cooked in water; in the process they will absorb large quantities of the liquid, and become once more pulpy and juiceful.

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* M. Vitmorin, President of the Botanical Society of France, in a lecture on "Salads," (March, 1890), stated that the French people excel in the use of salad preparations. He laid stress upon the nutritive value of salads as sources of potash and other mineral salts, which are commonly eliminated in the process of cooking. Among the various plants that are used as salads in France, he enumerated the leaves of lettuce, corn-salad, common chickory, water-cress, dandelions,(used green, blanched and half blanched), capuein, endives, purslane,(used in small quantities only), salsify tops, (described as being of a pleasant nutty flavor), witloof or Brussels chickory, roots of celeriac, rampion and radish; the bulbs of stachys, the stalks of celery, the flowers of nasturtium, and yucca, the fruit of capsicum and tomato, and, in the south of France, rocket, picridium and Spanish onions. Various herbs are added to a French salad as flavors or garnishes, such as chervil, parsley, olives, shallot, and borage flowers.

General Composition of Fruits.—The following table, compiled by Berard* shows the average chemical composition of five unripe and eight ripe fruits, comprising apples, pears, gooseberries, grapes, plums, cherries, apricots, and peaches:

	Unripe.	Ripe.
Water	85.7	78.7
Albuminoids	0.7	0.6
Sugar	4.0	12.9
Vegetable acids	1.5	1.3
Pectose and gum	4.3	3.7
Cellulose, etc.	3.8	2.8

4.—SEEDS.

Seeds represent in nutritive value the richest of ordinary plant products, being indeed the accumulations of food material which the plants have stored for their offspring. Leguminous seeds, or those that grow in pods, such as peas and beans, are among the most concentrated of vegetable foods. Analyses by Horsford and Krocker, show table peas to consist of:

	Per cent.
Albumen and Casein	28.02
Starch	38.81
Gum	28.50
Skin	7.65
Ash	3.18

The nitrogenous element of peas and beans is mostly vegetable casein, which has already been spoken of as the basis of Chinese vegetable cheese.

* Quoted in "Scientific American," Aug. 20, 1892.

REVIEW.

1. Why are potatoes not to be considered as true roots?
2. What do you know of the mineral ingredients of potatoes?
3. Show the abundance of starch in potatoes.
4. Explain the principal changes which a potato undergoes in cooking.
5. Define "boiling."
6. Show that potatoes alone form a very inferior food.
7. Define "tuber," "bulb," "root."
8. State what you know of onions as food.
9. Of turnips, carrots, parsnips, and beets.
10. Name the principal leaves used as food.
11. What do you know of cabbage as a food?
12. Wherein lies the value of raw salads, used moderately?
13. Name the principal salad materials in common use.
14. What do you know of fruits as food?
15. Of seeds?

CHAPTER 31.

VEGETABLE FOODS CONTINUED—GRAINS AND BREAD.

AMONG the most important of vegetable seeds used as food for man are the grains; and of these, wheat, barley, rye, oats, buckwheat, and rice are the kinds most commonly employed.

Wheat is the staple food stuff; its chief preparation, bread, has long been known as the "staff of life." The average composition of wheat may be represented as follows:

Water	11 to 15 per cent.
Gluten	12 to 18 "
Starch	53 to 64 "
Sugar	7 to 8 "
Gum	5 to 6 "
Bran	1 to 3 "
Ash	2 to 3 "

These figures are the results of numerous analyses of specimens from many different sources. When a thin section of a wheat grain, properly mounted, is examined under the microscope, a very regular arrangement of its constituent parts is revealed. Figure 95 represents a portion of such a section; *A* shows the coats of the seed; *B* marks a row of cells which are rich in gluten; *C* shows the interior cells containing starch granules.

The ash of wheat is particularly rich in phosphoric acid, and other mineral ingredients of great service within the body.

The first process by which wheat is prepared for use as human food is one of crushing or grinding; this is usually performed between stones or rollers. The resulting powder is then sifted and bolted, for the purpose of separating the coarse and fine particles. The outer layers of the grain, in the figure marked *A* and *B*, constitute the bran; this, as separated in milling, amounts to about 15 per cent. of the gross weight of wheat, though great variation exists in both the quantity and the composition of bran from different kinds of wheat, owing to the varying degrees of readiness with which the husks separate from the inner matter of the grain: in some cases the bran carries with it a considerable part of flour from within. Chemical analysis shows the bran to be richer in nutritive elements than is the interior flour; it is plain then that much valuable substance is lost from grain by the separation of the bran.

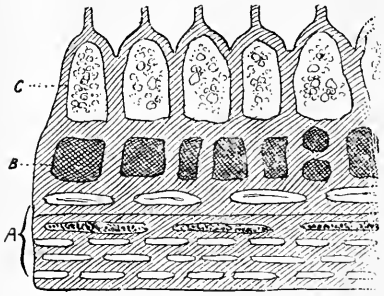

Fig. 95.
Part section of wheat grain.

Flour,—Whole-meal and Sifted.—The question as to the relative merits of sifted and of whole-meal flours has long been agitated. Certain it is that the superfine flours now in the market are sadly deficient in essential alimentary matters, which have been lost in the milling processes; and the results of experiment and of experience indicate a preference for whole-meal

flour, though such should be ground fine. It is known that the husk of wheat is liable to produce derangement of the digestive organs because of its coarse, irritating nature* and its comparative insolubility. The nitrogenous parts of the bran are mostly located in the inner layers of the husk; the outer layer of bran contains about 4.5 per cent. gluten; the inner part shows 18 per cent. It is therefore possible by removing the outer layers only to increase the proportion of nutritive ingredients in the remaining meal, at the same time rendering the flour more readily digestible.† Flour is now attainable of many degrees of fineness, with corresponding variations in color; the finest and whitest contain much starch, while the coarse and darker varieties show a larger amount of gluten and of mineral salts. It is plain then that the darker flours excel the superfine grades in nutritive value; and that whiteness in flour cannot be properly considered an indication of superiority.

Yeast, its Structure and Properties.—To pro-

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*"If the husk, which is demanded by the whole-meal agitators were as digestible as the inner flour they would unquestionably be right; but it is easy to show that it is not, and that in some cases the passage of the undigested particles may produce mischievous irritation in the intestinal canal. My own opinion on this subject * * * * is that a middle course is the right one, viz., that bread should be made of moderately dressed or 'seconds' flour, rather than overdressed 'firsts' or undressed 'thirds,'—i. e., unsifted whole-meal flour." MATTIEU WILLIAMS.

†"This removal of the outer fibrous coat involves a loss of about 2 pounds in 100 pounds of grain. It may be accomplished by moistening the grain and rubbing it, or by the special process of milling known as decortication." JOHNSTON.

duce the soft, porous, spongy bread, so justly esteemed as the basis of our foods, a quantity of yeast is commonly incorporated with the flour. Ordinarily yeast appears as a murky liquid, with a bitterish taste and an odor that is suggestive of beer. On standing, bakers' yeast usually deposits a heavy sediment, which consists mostly of potato pulp and other vegetable matters added in the making. The purest and best yeast is the brewer's "barm," which is developed in the beer vats during fermentation. As an aid to our understanding of the use of yeast a few experiments should be made. If a small quantity of yeast be put into fresh fruit juice or any saccharine solution, and the mixture be kept at a proper temperature, bubbles of gas are soon evolved, and alcohol is formed, while the sugar of the liquid disappears. These changes are included under the general name of fermentation. The gas referred to may be collected and tested; it will prove itself to be carbon dioxide.

Now let us examine a drop of yeast microscopically. With a proper magnifying power, we shall find it to be a collection of small, oval bodies, distributed through a watery liquid (figure 96). If yeast be filtered so as to separate the tiny bodies from the liquid, the latter does not excite fermentation in sweetened fluids; the corpuscles then are necessary to the efficacy of the yeast. If yeast be boiled, it loses its peculiar power of producing fermentative changes; this seems to be for the same reason that cooked potatoes and peas have lost their power of germination—the heat has destroyed the vitality of the organism. If yeast be

added to pure water, it does not develop, because there is lack of food materials; yeast so treated in reality starves to death. In a properly prepared solution, however, the yeast rapidly increases, so that if but a few drops of yeast be added the whole liquid will soon be swarming with yeast organisms. The vitality of yeast is suspended at a low temperature; this renders possible the preparation and use of "compressed yeast," which consists of yeast cells, freed from an excess of water, and preserved on ice in carefully wrapped packages. These facts prove that *the yeast corpuscles are in reality living organisms*; like other living things they grow in size and increase in numbers: they need food for their development; they may be starved, or may be killed by temperature too high or too low. Careful observations warrant the conclusion that the yeast organism is in fact a plant belonging to the fungi: to which class also belong common mildews or molds, mushrooms, toadstools and the like. It lives and breathes essentially as do other plants, though it possesses peculiar habits of its own. The carbon dioxide and alcohol already referred to as products of yeast fermentation are indeed the exhaled breath of the plant.

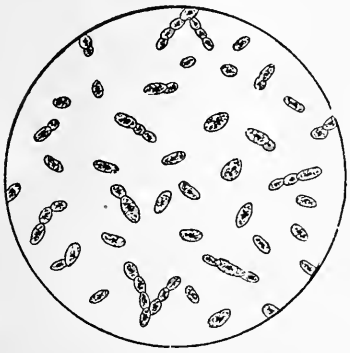

Fig. 96.
Yeast, as seen through the microscope.

Dough.—When wheaten flour is well moistened,

its particles cohere to form a soft, tenacious dough. If made from the best of flours; i. e., varieties rich in gluten, dough is very elastic and ductile; admitting of ready molding and rolling into thin strips. Dough that consists only of flour mixed with water is poorly adapted for the making of bread, as when baked it becomes hard, dense and brittle. Let us inquire concerning the action of yeast in dough-making. The yeast is placed in the flour, with proper admixture of food materials,—potato pulp, hops, sugar, etc.; the whole is then kept at a moderate temperature till fermentation begins, then flour and yeast are mixed, and thoroughly kneaded, by which process the yeast cells are distributed throughout the dough. Fermentation continues within the dough: the yeast plants thrive under the favorable condition of good food and proper temperature; and they exhale much carbon dioxide and alcohol vapor. These gaseous emanations by their buoyancy strive to escape from the dough, and in so doing cause a puffing of the latter, which results in a rising of the dough and the formation of a sponge.

Baking of Dough.—The dough is next to be molded and set in the oven; there the gases expand under the influence of increased temperature; much of the water present is converted into vapor, and adds to the buoyant effect; as a result the bread "rises" and becomes still more porous and spongy. The dough is partially dried, and the walls around the pores become sufficiently rigid to permanently retain their position and shape. When the temperature has

risen sufficiently, the yeast plants are killed and the fermentation is consequently stopped at the proper stage. The best temperature for bread baking is about 450° F.; this heat would completely char dry flour;* but evaporation of water from the dough takes place as the baking proceeds, and this renders latent much of the heat, and prevents a burning of the dough. Inside the loaf the temperature seldom far exceeds that of boiling water. The outer parts of the loaf are more highly heated than are the inner; in consequence a surrounding shell or crust is formed. In this crust much of the starch has been converted into dextrin; or if the loaf has been highly browned, some caramel may have been formed. Dextrin, it will be remembered, is soluble in water, and in some instances a glossy film of dextrin is found on the outside of the loaf. The crust possesses a slightly sweetish taste, and is more readily dissolved in the digestive fluids than is the crumb.

Bread, New, and Stale.—Freshly baked or new bread is tenacious, soft and apparently moist; if kept some days after baking, however, bread becomes hard, brittle, and seemingly much drier. Boussingault showed that the difference between new and stale bread is not entirely due to the drying process; in demonstrating this he kept a very stale loaf in a heated oven for an hour; during the operation the bread lost a

* Some bakers test the temperature of the oven by throwing a little flour upon the floor. If this blackens at once the heat is satisfactory.

quantity of moisture, becoming in reality drier, yet it came from the oven as a new loaf.*

Baking Powders.—Numerous substitutes for yeast in bread-making have been proposed; most of these are chemical mixtures, passing under the generic name of *baking powders*. The principle upon which such preparations act to render dough spongy, may be illustrated by mixing a little baking soda with dilute hydrochloric acid. As soon as the substances come together a copious evolution of carbon dioxide occurs; if such a liberation of gas should take place within the dough, it would cause the desired puffing and lightening of the latter. A common preparation of the sort consists of *sodium-bicarbonate, and hydrochloric acid*, in the proportion of one ounce of soda, to nine fluid drachms acid; these to be mixed with eight pounds of flour. Another product of the reaction between the acid and the soda, is sodium chloride or common salt, and as this is developed within the dough, and is therefore distributed throughout the mass, no other addition of salt is necessary in the process.

Many common baking powders contain *ammonium carbonate*, which substance decomposes when exposed to heat, and forms gaseous ammonia, carbon dioxide,

* "He [Boussingault] found that during the six days, while becoming stale, it only lost one per cent. of its weight by drying; and that during the one hour in the oven it lost three and a half per cent. in becoming new, and apparently more moist. By using an air tight case instead of an ordinary oven, he repeated the experiment several times in succession on the same piece of bread making it alternately stale and new each time." WILLIAMS.

and vapor of water. These gases expand within the dough and produce a porous mass. The use of ammonium compounds is objected to for hygienic reasons; yet baking powders of this sort are in commoner use than is generally supposed; and a person may daily purchase of our city bakers fresh hot cakes and biscuits all strongly smelling of hartshorn.

Alum Baking Powders are considered objectionable by most hygienists. It has been proved that constant doses of alum will surely prove of detriment to health; though the quantity taken at a single eating of alum bread is small. The chief reason for adding alum to dough, is to secure an increased whiteness in the bread; this object it accomplishes admirably, though the mode of its operation is not well understood. The "rocky" used by British bakers consists, according to Tomlinson, of one part alum and three parts common salt.

Aerated Bread.—Attempts have been made to introduce aerated bread to popular favor. To prepare this kind of bread, dough is made without admixture of yeast or baking powder; this is then inflated and puffed by having air or carbon dioxide forced into it under high pressure. Bread so prepared has a peculiar "flat" taste, not at all appreciated by most people.

Barley and Rye.—Next to wheat, these claim our attention as food grains. These are both allied in composition to wheat. The following analyses by Poggaile are illustrative:

	Barley. Per cent.	*Rye.* Per cent.
Water	15.22	15.53
Albuminoids	10.65	8.79
Starch, dextrin	60.33	65.53
Fat	2.38	1.99
Woody fibre	8.78	6.38
Ash	2.62	1.77

Barley, though rich in nitrogenous matter, is deficient in true gluten, and is therefore not adapted for making dough. Hulled barley is the grain after the removal of its husk; and pearl barley consists of the inner parts of the kernel only. Rye contains more saccharine matter than does either wheat or barley. Its bran possesses an aromatic flavor, which is appreciated by many. The nitrogenous matter of rye is closely allied to casein; it has been called soluble gluten.

Maize or Indian corn is rich in fatty matter, though, on the whole, it is less nutritious than is wheat. Its nitrogenous ingredient is peculiar; unlike true gluten it is not adhesive, and corn bread in consequence crumbles readily. Compare the following analysis (by Poggaile) with the other analytical data already cited. Yellow maize contains:

	Per cent.
Water	13.47
Nitrogenous matter	9.90
Starch, dextrin, sugar	64.53
Fats	6.68
Woody Fibre and coloring matter	3.97
Ash	1.44

Corn meal readily spoils; this is due to the ease with which the fatty matter undergoes oxidation. Crushed corn divested of its outer skin is known as hominy.

Oats are in some parts of the world more extensively used as food for men than in this country. In nutritive value, that is as a flesh producer, oat-flour excels all other grain preparations. Oats are rich in oily matter. Meal from oats is used mostly in porridge or gruel, though oat cakes are esteemed by those who have learned to know their merits. The following table represents the composition of dry oats; it will be observed that the characteristic nitrogenous matter has received the special name, avenin (from avena, meaning oat):

	Per cent.
Water	14.3
Avenin, Albumen, Gluten	12.0
Starch, sugar, gum	54.9
Fat	6.0
Woody fibre	10.3
Ash	3.0

Buckwheat is highly nutritious, being in some respects almost equal to wheat.

Rice differs from most other grains in being richer in starch, and more deficient in oil and nitrogenous matters. The albuminoids are not more than half as abundant as in oatmeal. Some samples of rice contain over 80 per cent. starch, though the average is lower. Johnston gives its composition as:

	Per cent.
Water	14.5
Fibrin	7.5
Starch	76.0
Fat	0.5
Fibre	1.0
Ash	0.5

Sago, tapioca, arrowroot, are all rich in starch; likewise are they easily digested, but are very incomplete foods when eaten alone.* Nitrogenous and fatty matters should be added to them.

REVIEW.

1. Name the principal grains used as food for man.
2. State what you know of the average composition of wheat.
3. Describe the structure of a wheat grain as revealed by the microscope.
4. How is wheat prepared for use as human food?
5. Give reasons for your opinion as to the relative values of sifted and whole-meal flours.
6. Explain the preparation of dough.
7. What is the purpose of adding yeast in making dough?
8. How is yeast prepared?
9. What does the microscope teach us respecting the nature of yeast?
10. What proof have you that yeast contains living organisms?
11. Explain the "rising" of dough.
12. Explain the changes taking place as dough is baked into bread.
13. Describe the difference between crust and crumb of bread.
14. Explain the difference between new and stale bread.
15. What are baking powders?
16. What effect has a small amount of alum when mixed with dough?
17. What do you know of barley as food?
18. Of rye? Of maize? Of oats? Of buckwheat? Of rice?

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*Some people regard arrowroot, tapioca, and sago preparations as admirable foods for invalids; and without doubt many a patient has been in danger of starving to death through this ignorance on the part of kindly-disposed nurses. Starch is not a tissue-forming food, and to be measurably nutritious such farinaceous dishes should be enriched with good milk or eggs. Starchy foods are not adapted to the digestive conditions of infants.

CHAPTER 32.

ANIMAL FOODS AND THEIR COOKERY; MEAT AND EGGS.

Flesh as Food.—All kinds of lean flesh are rich in nitrogenous ingredients, principally as myosin, fibrin, and albumen. Fresh meats contain a very large proportion of water; lean beef is nearly 80 per cent. water. All meats, even the leanest, contain a considerable proportion of fat, which during the life of the animal existed within the body as oils. The following analysis (by Schurtz) of pure lean beef is instructive:

	Per cent.
Fibrin and myosin	15.0
Albumen	4.3
Extractive matters, soluble in water	1.8
" " " " alcohol	1.3
Phosphates	traces
Fat	0.1
Water	77.5

This may be taken as a type of lean meats generally, though considerable variation exists among meats from different animals. Veal and venison are generally deficient in fat; pork on the other hand is excessively oily. As a rule, the flesh of wild animals contains but little fat, whereas domesticated animals, even if in poor bodily condition, contain relatively much oily matter. The analysis quoted above is of pure lean muscle as free from fat as it was possible to

procure the same; ordinarily, however, meat contains several per cent. of fat; of dry meat substance, fully one-fourth is fat. The flesh of birds generally contains less fat than does meat from quadrupeds, though some birds when kept in captivity may be artificially fattened.

Fish of different kinds show varying contents of fat. The flesh of all fish is rich in albuminoids, and in mineral salts, especially phosphates; some kinds, however, as trout, whiting, sole, and carp are comparatively poor in fats, while salmon, eels, and others are particularly rich in oil.

Cookery of Meat—Seething.—As a rule, meats and fish in a fresh state are readily digested; among meats, veal and pork are comparatively difficult to digest. Cooking is productive of many great changes in the condition of meat. If meat be immersed in cold water, much of its albumen and many of its sapid juices and mineral salts will be washed away, and little more than the juiceless myosin will remain. If meat must be seethed (or as it is improperly said, "boiled") let it be done by immersing the flesh in boiling water at first; the effect of this will be to harden the albumen in the superficial parts of the meat, and produce an outer protecting layer by which the inner juices will be retained. The cooking should then be completed at a lower temperature; not above 165° F.; for it will be remembered that the heat of boiling water is effectual in hardening albumen into an indigestible mass. Under the best conditions, seething is a poor mode of cooking meat, except in

making stews, in which case the watery extract and the solid residue are eaten together.*

The Water-bath.—To guard against undue heat, it is well to conduct the cooking of albumen in a steam-bath or water-bath. The essential features of the latter are represented in figure 97; *A* is an outer vessel, containing water, into which the cooking-receptacle, *B*, is fitted. The contents of *B* will not be raised to the full temperature of boiling water.

Soup-making.—In the preparation of soups, however, an opposite course from that designed to retain the juices is indicated. In such a case it is desirable to extract the meat juices and this is best done by subjecting meat in a minced state, to the action of cold water, the resulting extract of meat may be afterward heated and flavored. The heating, however, should be carefully regulated, else the temperature may rise to the point of coagulation of the contained albumen, which will then separate in shreds or flakes, and the careful cook will be sure to remove these floating bits, and thus will lose some very valuable material. Myosin or animal

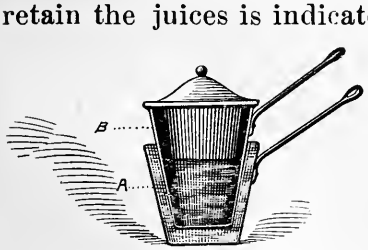

Fig. 97.
Water-bath.

*"It should be boiled only for a few minutes, and then kept for some time at a temperature from 158° to 165°. Meat is underdone or bloody when it has been heated throughout only to the temperature of coagulating albumen (140°); it is quite done or cooked when it has been heated through its whole mass to 158° or 165°, at which temperature the coloring matter of the blood coagluates." YOUMANS.

fibrin is practically insoluble in cold water; it is therefore impossible to extract it by maceration, and although treatment with cold water will remove most of the sapid constituents of the meat, together with some gelatin and mineral salts, leaving only a fibrous residue which is almost tasteless, and if eaten alone, actually nauseating, still the extract without the fibre is a very poor diet. Many sick people have been almost starved on a beef tea regimen.* All kinds of meat extracts, of which there are many now in the markets, are deceptive as to their true nutritive value.

Roasting if properly conducted will produce far better results than are possible in seething. In the roasting process, meat should be exposed at the beginning to an intense heat,—the best effects are obtained from an initial temperature of 400° F.; by such means the surface albumen is hardened, and an impervious layer is formed about the inner parts in which the juices are held. This temperature should be maintained for a short time—for small joints about

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* Dr. Martin says of beef tea:—"The flavoring matters make it deceptively taste as if it were a strong solution of the whole meat, whereas it contains but a small proportion of the really nutritious parts, which are chiefly left behind in tasteless shrunken shreds when the liquid is poured off. Some things dissolved out of the meat make beef tea a slight stimulant, but its really nutritive value is small, and it cannot be relied upon to keep up a sick person's strength for any length of time. Liebig's extract of meat is essentially but a concentrated beef tea; from its stimulating effect it is often useful to persons in feeble health, but other food should be given with it. It contains all the flavoring matters of the meat, and its proper use is for making gravies and flavoring soups, the erroneousness of the common belief that it is a highly nutritious food cannot be too strongly insisted upon, as sick persons may be starved on it if ignorantly used."

one-sixth of the entire time required for complete roasting,—the heat should then be reduced and the subsequent cooking allowed to proceed at 200° F. The gravy of roasted meat consists of melted fat and some juice that has found its way out of the joint.

In baking meats, a vessel of water should be set in the oven that the heated air may be well supplied with liquid; else as its capacity for moisture increases with the rising temperature it will absorb the fluid parts of the meat and produce a disagreeable dryness of the joint. By the old-time style of spit roasting, it was necessary to constantly baste the meat by pouring melted fat over the surface, otherwise a deplorable loss of juice would have occurred. Such fish as is naturally poor in oil should be coated with grease during the cooking operation, to aid in the retention of its juices.

Broiling or Grilling is a common method of cooking small pieces of meat, such as steaks, chops, and cutlets. The meat should be exposed to the high heat of a bright and smokeless fire; the result will be a rich, juicy morsel; whereas slow cooking will produce a dried ill-flavored piece, alike unattractive to eye and palate.

Frying, among all common operations of cooking is perhaps the most objectionable from a hygienic point of view. As ordinarily performed, the frying process consists of smearing a thin layer of fat on the bottom of a frying-pan, placing therein the thing to be cooked—say for example a piece of meat—and heating the whole over a fire. But one side of the

piece will be heated at a time, and though the under surface may be browned, the upper side remains uncooked long enough to allow the escape of juices from within. Some fat will be absorbed by the meat, and the fibres becoming thus coated will resist the subsequent action of the digestive fluids. The great mistake in ordinary frying lies in proceeding as if the cooking depended upon direct conduction of heat from the fire through the iron floor of the pan to the meat, the fat being regarded as useful only in preventing the meat from sticking to the metal. The fat should be sufficiently abundant to envelop and surround the meat, as by such method only can heat be communicated uniformly on all sides. Good cooks are now abandoning the frying pan for the frying kettle; an illustration of the latter device is here reproduced (figure 98, after Gouffe). The vessel is a deep one; a movable tray of coarse-mesh wire (shown here removed) rests within an inch or two of the bottom. Sufficient fat is placed within to completely cover this tray when the latter is in position. The fat is highly heated, and the thing to be cooked is then placed upon the wire support, completely immersed in the oily bath. The effect of this method is to heat the object on all sides, and to retain most of its juices. Contrary to ordinary expectation, experiment shows that such a bath of fat may be used for fish, meats,

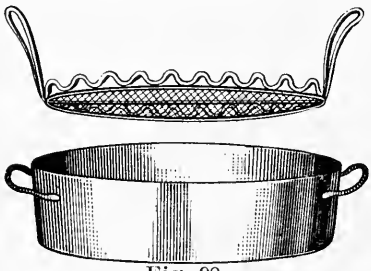

Fig. 98.
Frying kettle.

vegetables, and fruits in succession, without communicating the flavor of one to the others. The employment of so large a quantity of fat is not as extravagant as would at first thought appear, as less is absorbed by this process than by the greased pan method. When necessary, the fat may be purified by removing its suspended particles which readily separate as sediment or scum.

Eggs constitute an important item of animal food. Those of domestic fowls, ducks, geese, and turkeys are commonly used. An examination of an egg will show it to consist of shell, white, and yolk. Of these the shell is discarded from food, the other parts are eaten. The white of egg is almost pure albumen; the yolk consists mainly of water, albumen, and a peculiar oil, bright yellow in color and containing compounds of sulphur and phosphorus. This oil forms nearly two-thirds by weight of the perfectly dry yolk. The fat of the egg is concentrated in the yolk, the white being poorly supplied with oily matter. The composition of eggs, exclusive of shell, will be understood from the following table (Johnston).

	White. Per cent.	Yolk. Per cent.	Whole egg. Per cent.
Water . . .	85	51.5	71.75
Albumen . .	12	15	14
Fat, etc. . .	2	32	13
Phosphates, etc. .	1	15	1.25

In cooking eggs it should be remembered that the albumen is completely coagulated at a temperature below 160° F.; and any higher heat will harden the substance. The old-time method of cooking eggs in

the shells was to keep them in boiling water for three minutes; "egg timers" were made on the principle of the hour glass; as soon as the eggs were immersed the glass was turned, and when the sand had run its course the eggs were considered done. A better method consists in placing the eggs in water that is near the boiling temperature, allowing about a pint of water to each egg. The eggs will share the heat of the water and the temperature will be reduced to the required degree, and the cooking will proceed without danger of over-heating. The vessel containing the water and eggs should of course be set aside from the fire; the eggs cannot become hard even by prolonged exposure to water below 160° F.

REVIEW.

1. State what you know of the relative food values of some common meats.
2. What is the effect of placing lean meat in cold water?
3. What is the effect of hot water on lean meat?
4. What do we learn from these facts, as to the proper means of cooking meat?
5. Describe the water-bath.
6. Of what value is the water-bath in cooking?
7. What is meant by seething meat?
8. What do you know of the value of beef tea as a diet for invalids?
9. Explain the changes taking place in the roasting of meat.
10. Explain the difference between roasting and baking meats.
11. Explain the process of broiling meat.
12. Describe the ordinary method of frying.
13. Show the use of the frying kettle.
14. What do you know of eggs as food?
15. What is the proper cooking temperature for eggs?

CHAPTER 33.

ANIMAL FOODS CONTINUED; MILK, BUTTER, AND CHEESE.

Milk constitutes the sole food of infants and of the young of many animals; this fact is proof of its nutritive value. Chemically, milk consists of a large proportion of water in which is dissolved sugar, casein, and mineral salts, while oil or butter particles are suspended in the fluid. The following table represents the mean composition of milk from different sources:

	Cow	Goat	Ewe	Human Milk
Water	87.02	86.80	85.62	88.90
Casein (curd)	4.48	4.08	4.50	3.90
Fat (butter)	3.13	3.32	4.20	2.67
Sugar of milk	4.77	5.28	5.00	4.36
Saline matter	.60	.52	.68	.14

A drop of milk, when viewed through the microscope, appears as a collection of many floating globules; such a view is represented in figure 99. Milk, therefore, is both a solution and an emulsion. New milk is slightly alkaline; this property assists in keeping the fat globules in suspension. Oil and pure water may be agitated together,

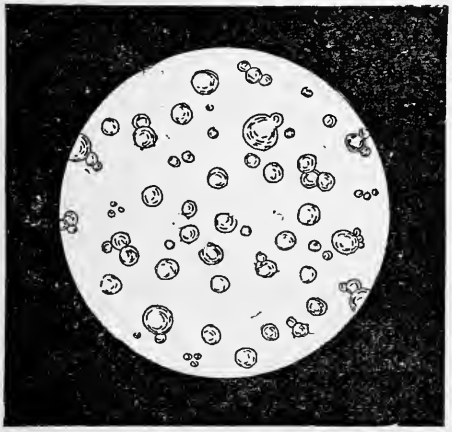

Fig. 99.
Milk viewed through the microscope.

yet as soon as the liquids come to rest they separate; but if the liquid be first rendered slightly alkaline, the oil by shaking will become more finely divided, and part of it will be permanently distributed through the water. As milk sours it becomes less able to hold fat globules in suspension.

Milk is used in its raw state, though boiled milk is a constituent of many prepared dishes. In boiling, the albumen of milk coagulates and appears upon the surface as a scum; this coagulum is impervious to steam, consequently vapor cannot readily rise from the heated liquid, and the milk "boils over" if the heat be continued. All milk of unassured wholesomeness should be boiled before being used, as a precaution against the possible communication of disease germs. Many contagious diseases have been spread through the medium of impure milk.

Milk is a nutritious food, though it is not adapted as the sole aliment of adults. It is a common supposition that milk is apt to produce troubles of indigestion; yet children live upon it while their digestive organs are still weak. Ill results are likely to follow the rapid drinking of large quantities of milk, because the liquid curdles in the stomach, and if it be unmixed with gastric juice, its assimilation within the body will be long delayed. Milk should be drunk slowly; it should be sipped only, so as to imitate in some degree the natural method of swallowing milk directly from the lacteal glands. If milk be used as a beverage, a corresponding diminution in other animal foods should

be made, else the consumer may suffer from over-nutrition.

Cream.—The fat globules of milk are lighter than the rest of the fluid; consequently they rise and form upon the surface an oily layer, which is mingled with considerable casein or cheesy matter, and constitutes the cream. Not all the fat so rises, considerable still remains in "skim milk." The larger globules of fat rise first, and the cream that first forms is richer than that which appears subsequently; the dairy custom of skimming milk twice is a good one, as thereby may be obtained a quantity of richer and better flavored cream. Fat globules cannot readily rise from great depths of liquid; it is therefore customary to set milk in shallow pans till the cream has risen. In large dairies it is now customary to employ mechanical separators, whereby the cream is rapidly removed from the milk without the long interval of setting.

Butter.—By churning, the fat globules of milk are brought together to form *butter*. Most of the water, casein, and mineral salts remain in the butter-milk. As ordinarily made butter contains about 10 per cent. water, 2 per cent. casein (or curd), milk-sugar, and salt, and about 88 per cent. fats. It possesses in addition to these certain aromatic compounds of butyric acid, to which the peculiar flavor of fresh butter is due. Inferior butters contain much water and salt.

Many so-called **Artificial Butters** have of late years been manufactured under the names of margar-

ine, oleo-margarine, and butterine. These substances consist of soft animal fats mingled with true butter. In the preparation of such, animal suets are minced, heated and pressed, so as to yield their softer portions in a liquid state; this oily matter is then filtered, mixed with milk, and churned. As a rule these adulterated butters are manufactured with care and cleanliness; only good fats are used in the process, and both chemically and physiologically such preparations are as wholesome and almost as nutritious as is true butter. It is no less a deception, however to sell them under the name of butter. Instead of seeking by legislative enactment to forbid the manufacture and sale of imitation butters, it would seem wiser to enact laws requiring such products to be sold under their true names and at a fair price.*

Cheese may be regarded as the pressed and salted casein of milk. Milk may be curdled in many ways. If left to itself it undergoes the change spontaneously; acid may be artificially added to produce curd; but the best method of causing coagulation is by the addition of rennet, which consists of the salted stomach of a sucking calf or pig. As the casein coagulates, it takes with it a considerable amount of fat, together with some sugar and water, leaving most of the water, sugar, and mineral compounds in the whey. In precipitating curd by acid, many mineral ingredients are lost in the

*The author has analyzed and practically tested many artificial butters, and he is convinced that good oleomargarine is far preferable in flavor and wholesomeness to inferior butter; yet he is none the less disgusted that he has had to pay butter prices for that which was not butter.

whey, whereas by the use of rennet they are retained in the curd.* Cheese is sometimes made from cream; such cheese is of a very oily nature and is prone to rapid decomposition. Cheese made from unskimmed milk is considered best; though that made from skimmed milk is rich in casein, but deficient in fats. The following table (by Johnston) represents the relative composition of whole milk and skimmed milk cheese:

	Cheddar, whole milk cheese. Per cent.	Skim milk cheese. Per cent.
Water	36	44
Curd or casein	29	45
Milk fat	30.5	6
Salt and phosphates	4.5	5

As a food, cheese is not generally appreciated according to its merits. It contains fully twice as much nutritive solid matter as does the best selected meats. Cheese is by many considered to be difficult of digestion and generally productive of ill results. Undoubtedly if eaten in large quantity, in addition to other highly nutritive foods, the bad effects of excessive nutrition will be manifested. Cheese should be used to supplant, not simply to supplement, other animal foods. By proper cooking, cheese may be rendered easy of digestion.†

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* "Casein that has not been treated with acids contains about 6 per cent. of phosphate of lime." LEHMANN.

† Mr. Mattieu Williams, of London, has reported many trials upon the relative merits of raw and of cooked cheese. He says: "I may here mention that I have recently made some experiments on the dissolving of cheese, by adding sufficient alkali

REVIEW.

1. State what you know of the nutritive value of milk.
2. Describe the microscopical appearance of milk.
3. Explain the changes effected in milk by boiling it.
4. Explain the rising of cream.
5. Explain the process of churning.
6. What do you know of artificial butters ?
7. What is cheese ?
8. By which two methods may the casein of milk be coagulated in the manufacture of cheese.
9. What advantage belongs to either of these methods over the other ?
10. Compare the nutritive value of whole milk cheese, with that of skim-milk cheese.
11. State your opinion of cheese as a food.

(carbonate of potash) to neutralize the acid it contains, in order to convert the casein into its original soluble form as it existed in the milk, and have partially succeeded both with water and milk as solvents.

CHAPTER 34.

SOME AUXILIARY FOODS.

Beside the classes of true foods already referred to, there are certain substances which are commonly used in diet, not for their nutritive worth, but to impart attractive flavors to regular food. These are sometimes called *condiments*.

Vinegar is one of the commonest of condiments. It is produced by the acetous fermentation of saccharine solutions and fruit juices, such as cider and wine. Its essential ingredient is acetic acid, of which ordinary vinegar contains about four per cent. Commercial vinegars vary greatly in strength; however, the so-called "proof" vinegar contains 4.6 per cent. acetic acid. According to their source and mode of preparation, common vinegars are described as malt vinegar, spirit vinegar, cider vinegar, and wine vinegar. Aromatic vinegars are artificially flavored and perfumed. It is generally believed that small quantities of vinegar may aid digestion by increasing the solvent power of juices within the stomach. Many albuminoid matters are partially soluble in dilute acetic acid.

Vinegar from fruit juices usually possesses a peculiar aroma indicative of its source. White vinegar is without aroma; it is a simple mixture of acetic acid and water, and may be cheaply prepared by adding pure acetic acid to water to produce the required degree of

acidity. If the absence of color be an objection, a very rich tint may be imparted by adding a little caramel or burnt sugar. Occasionally vinegar is adulterated with sulphuric acid; this is an injurious addition, and a competent chemist will readily detect the presence of the poisonous acid in any sample.

Pickles are prepared by treating various vegetable products with brine and vinegar. They are used solely as condiments. If eaten in large quantity, pickles will certainly prove of detriment to the body. Pickling operations should be conducted in vessels of porcelain, stoneware or glass only. Acetic acid will attack metallic vessels, and form poisonous salts. The bright tints so much admired in bottled pickles are frequently due to the deadly copper acetate, formed by the action of pickling fluids on copper or brass kettles used in the process.

Lemon, and Lime Juices are sometimes used as substitutes for vinegar. When mixed with water, they form agreeable beverages. Both substances are rich in citric acid, sometimes containing as high as 30 grains of acid to the fluid ounce of juice. A moderate quantity of these substances is of decided benefit to the body; they are of medicinal effect in counteracting any tendency to scorbutic diseases. By the use of lime juice, scurvy has been checked among Arctic navigators who have been long confined to a salt meat diet.

Certain Essential Oils are used for flavoring purposes; such are oil or essence of lemon, orange, vanilla, nutmeg, banana, pine apple, etc. In large doses all of these substances are active poisons, but

the amount ordinarily employed is so very small that no serious result need be feared from their occasional use. Many of the essential oils are largely and some injuriously adulterated, however.

Spices and other aromatic compounds are also in common use as condiments. Among such may be named pepper, black and red; mustard and cloves in the plain state, or prepared in sauces; horse radish, and many other substances. Savory herbs may be advantageously substituted for more stimulating condiments; thyme, parsley, sage, sweet majoram, and mint, are in common and beneficial use.

Salt, though in some sense a condiment, is still an essential ingredient of food.* It has received attention in a former chapter. (See page 262.)

Danger from Condiments.—Danger attends the frequent eating of stimulating condiments; the digestive organs may be so habituated to the presence of such substances, that plain food seems insipid. The general effect of highly seasoned food is to produce an irritation of the intestinal tract, with strongly marked nervous affections.†

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*"Hard work and attendant good appetite require little else than common salt as a condiment, which should be plentifully used. It was said by Plutarch that hunger and salt were the only sauces known to the ancients, and the very word 'sauce,' is derived from the Latin word *salsus*, salted.'"—McSHERRY.

†Dr. Beaumont says: "Condiments, particularly those of the spicy kinds, are not essential to the process of digestion, in a healthy state of the system. They afford no nutrition. Though they may assist the action of a debilitated stomach for a time, their continual use never fails to produce a weakness of that organ. They affect it as alcohol or other stimulants do:—the present relief afforded is at the expense of future suffering."

Certain Artificial Drinks, may with propriety be classed under the title of auxiliary foods. All beverages other than water or milk, may be so regarded; though we would best exclude from the list alcoholic liquors of all kinds; none of which, from a chemical or a physiological standpoint, can properly be classed as foods, except by reason of the small proportion of sugar and extractive matters which they contain. Alcohol, though consisting of carbon, hydrogen, and oxygen, is not digested or assimilated within the body. Liebig, the noted chemist, declared that the small quantity of flour, which can be picked up upon the point of a knife, contains more nutriment than two gallons of the best beer.

Tea as ordinarily prepared, is an infusion of the dried leaves of the tea plant, a small shrub which is grown mostly in China. Under cultivation, the plant grows from three to six feet in height, and reaches maturity in two years; it yields three crops of leaves per year. The first crop of the season furnishes the youngest, tenderest, and most fragrant leaves. The tea leaves are gathered by hand; while fresh, they possess none of the fragrance of dried leaves. They are subjected to a complicated roasting in open vessels with frequent shaking and rolling; by this process some water is expelled, the color of the leaves is changed, and their aromatic properties are developed. The difference between green and black tea is mainly dependent on the preparation, though some choice is indicated as to the species best suited for one kind or the other.

Chemical analysis shows tea to contain a volatile oil, theine, tannin, and gluten. The *oil of tea* is volatile, and strongly aromatic; to it is largely due the flavor of tea. The potent properties of this substance are illustrated by the fact that a hundred pounds of leaves contain less than half a pound of the oil. Its effect upon the human system is shown in nervous disorders; and in the separated state it is known to be a powerful poison. Tea drinkers, professional tea-tasters, and especially packers of tea leaves, are subject to headaches, giddiness, and in severe cases even paralysis. *Theine* is a white, crystalized solid which may be readily sublimed from dried tea leaves. It belongs to the chemical family of alkaloids, all of which are of a poisonous nature. In small doses, it stimulates the body, and to its action is due the deceptive feeling of increased strength to the habitual tea-drinker. Teas of medium quality contain from 2 to 3 per cent., and exceptional samples have shown even 6 per cent. of the alkaloid. *Tannin* is the astringent principle of tea; the substance is so named from its abundant occurrence in oak bark, which is used in tanning. Tannin and tannic acid produce inky infusions with water containing iron. It aids in producing the stimulating effect which usually follows an indulgence in tea drinking. *Gluten* is present in tea to the extent of 20 to 25 per cent. As the substance is insoluble in water, it is not extracted in the infusion, but is lost in the dregs.

The infusion of tea contains the soluble matter, including the tannin and volatile oil. If the steeping be

done in a closed vessel, a very fragrant liquid results. The tannin is extracted after long steeping; the volatile oil, however, is expelled by prolonged heating; to procure at once a fragrant and strong infusion, two lots of leaves should be steeped,—one for a few minutes only, the other for a longer time; the two infusions should then be mixed.

Coffee is an infusion of certain roasted seeds, the commonest being derived from the coffee tree. In a cultivated state this tree reaches a height of 6 to 10 feet. The seeds are very improperly called "coffee beans" and "coffee berries." The best quality is Mocha coffee, then follow, in order, the coffees of Java, East India, Ceylon, and Brazil. Coffee seeds contain a volatile aromatic *oil*. This is present in such small quantity that 50,000 pounds of the coffee seeds would yield but one pound of the oil. Payen says the oil could not be prepared and sold at a lower cost than $500 an ounce. Coffee seeds contain also *gluten*; an alkaloid known as *caffeine*, now supposed to be identical with theine, and an astringent principle *caffeo-tannic acid*, analogous in properties to the corresponding ingredients of tea.

Tea and Coffee Drinking.—The general effect of tea and coffee is to produce a stimulation of the nervous system, which is followed by a reactive depression. Long continued indulgences produce specific derangements to which the name "tea disease" has been applied. The custom among students of drinking coffee to keep them awake is suicidal. The system may be habituated to these as to any other

stimulants, and when their use is discontinued serious discomfort results.* The habit is an enslaving one; it makes man dependent on drugs for the exercise of his powers. Such habits are cords that bind mind and body in the discharge of their functions. The substances are potent medicines, and should be used with great wisdom. As indulgences they are not good for the body.

Cocoa and Chocolate are prepared from the cocoa or cacao seed, which is produced in South America, and the West Indies. These seeds are particularly rich in fatty matter, to which is given the name *cocoa butter*. This exists in the bean to the extent of over 50 per cent. An alkaloid body is present in the beans; this is called *theobromin*; it is similar in properties to theine. The ground beans, sometimes mixed with sugar, and often fraudulently adulterated with starch and flour, etc., compose cocoa. If the product be flavored and seasoned, it is called chocolate. Cocoa and chocolate as prepared for the table, are not mere infusions, but rather in the nature of soups or gruels. All the nutriment of the solid therefore enters the body. All the prepared cocoas

* "I recommend tea drinkers who desire to practically investigate the subject for themselves, to repeat the experiment I have made. After establishing the habit of taking tea at a particular hour, suddenly relinquish it altogether. The result will be more or less unpleasant; in some cases seriously so. My symptoms were a dull headache and intellectual sluggishness during the remainder of the day,—and if compelled to do any brain work, such as lecturing or writing, I did it badly. This, as I have already said, is the diseased condition induced by the habit. These symptoms vary with the amount of the customary indulgence, and the temperament of the individual."—WILLIAMS.

and chocolates of the market are largely adulterated,* and the proportion of active ingredients introduced into the body by drinking the beverage is correspondingly diminished. The pure cocoa bean would exert stimulating and narcotic effects analogous to those resulting from the use of tea or coffee.

REVIEW.

1. What is meant by auxiliary foods?
2. Define "condiments."
3. Name the principal condiments in common use.
4. What is vinegar?
5. Describe briefly the preparation of vinegar.
6. What do you know of the strength of commercial vinegars?
7. What special characteristic is possessed by fruit vinegars?
8. Explain the preparation of pickles.
9. What precautions should be taken as to the material of the vessels in which pickles are made and kept?
10. What do you know of lemon and lime juices as condiments or as ingredients of beverages?
11. Name the principal essential oils used as flavors.
12. What do you know of salt as a condiment?
13. Name the principal artificial drinks that are used as auxiliary foods.
14. Describe the growth and preparation of tea.
15. What do you know of the chemical composition of tea?
16. State the properties of the volatile oil of tea.

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* The common adulterants of cocoa are often of a disgusting kind. The following is on the authority of Dr. Youmans who quotes from Normandy: "I have known cocoa powder made out of potato starch moistened with a decoction of cocoa-nut shells and sweetened with molasses; chocolate made of the same material with the addition of tallow and ochre—a coarse paint. I have also met with chocolate in which brick dust or red ochre had been introduced to the extent of 12 per cent."

17. Of theine.
18. Of tannin.
19. State what you know of the growth of the coffee plant.
20. What do you know of the volatile oil of coffee?
21. What is the source of the cocoa of commerce?
22. What is the difference between cocoa and chocolate?
23. What do you know of the common adulterants of cocoa?
24. State the general physiological effects of tea or coffee drinking.

CHAPTER 35.

PRESERVATION OF FOOD STUFFS.

Decay of Organic Matters.—All organic matters, to which class of substances our ordinary food stuffs belong, easily undergo decay. In this process certain of their elements are separated and then re-combined in different proportions, producing compounds entirely unlike the original. Were it not for such ability of ready change, easy digestion of foods would be impossible, for this bodily process is one of change in which new and strange products are formed from the elements of food. With nitrogenous compounds, the process of decomposition is known as putrefaction, and the products are usually disgusting to our senses. Decomposition and re-composition changes of a less disagreeable nature, especially such as occur in carbohydrates, are spoken of as fermentation. From very early times, man has striven to devise a method of preserving food by artificial means, so as to prevent these destructive changes. Let us first consider the nature of the decomposition process.

Bacteria and Decay.—Whenever putrefaction of organic matter is in progress, the microscope reveals within the substance the presence of many tiny forms of life, the chief appearances of which are shown in figure 100. These tiny organisms have received the

generic name of *bacteria*, from a word meaning little rod or staff, and so applied because of the rod-like shape of the typical and commonest form. The bacteria are known to belong to the kingdom of plants, and to the order of fungi; they are, therefore, closely related to the yeast plant. A discussion has been indulged in among scientists, as to whether the presence of bacteria is the cause of decay, or decay the cause of bacteria being present; we may leave the contestants to their own dispute and accept these facts, which both parties admit, that spontaneous decay of organic matter is not known to occur unless such organisms are present; and, farther, that any method by which these tiny structures may be excluded or killed, will arrest or prevent putrefaction.

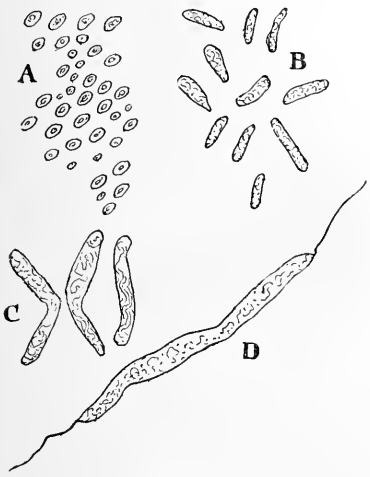

Fig. 100.

Bacteria.
(Very highly magnified.)

Freezing constitutes a time-honored mode of preserving food substances. It is well known that decay is more rapid in summer than in winter; and this is perhaps partly due to the inactivity of bacteria at low temperatures. Perishable foods are usually kept on ice; refrigerators or ice boxes are now in common use for this purpose. Carcasses of sheep and cattle are shipped in a frozen state from Australia and New

Zealand to Europe, and the meat is eaten months after the time of death.* Chemical analysis fails to reveal any objectionable properties in frozen meat, though practical experience demonstrates a great superiority of fresh flesh over preserved meats of any kind.

Canning, Bottling, etc.—Food stuffs are often preserved by *hermetic sealing* in cases. Meats are usually kept in cans; fruits in bottles. In canning or bottling, the food material is placed in the vessels and heated to the boiling point of water, in order to destroy the bacteria present; the cans are then securely closed by having the tops soldered in place, and the bottles are closed by tightly fitting screw-lids. If the process be thorough, all bacterial organisms there present being killed, and others prevented from gaining access, no decomposition will take place. It has long been supposed that this preservative effect is due to the exclusion of air, and that oxygen is the chief agent of putrefactive changes. It is true that the chemical changes of decay are processes of oxidation; but that spontaneous decomposition is closely associated with bacterial life is equally certain. Prof. Tyndal and other eminent experimenters have conclusively shown that *air thoroughly cleansed from all*

* As an example of the prolonged preservation of flesh through the agency of ice, consider the following: "In the year 1799 a Siberian fisherman saw a rounded mass projecting from an ice bank near the mouth of the rive Lena. The summer weather so thawed it year after year, that in 1803 the enveloping ice was all melted and the nucleus of this mound-like projection was found to be an enormous elephant (known as the mammoth). Though it had been there not merely centuries, but ages, it was perfectly preserved, so that dogs and wolves fed upon it as upon fresh meat." HOOKER.

germs of life may be freely admitted to perishable articles without causing decomposition. Air may be so cleansed in many ways, by being passed through a heated tube, thus burning to death the bacterial organisms; or by thoroughly washing by means of a spray of water, by which the organisms will be stopped; or by being strained through a thick filter of cotton fibre. The writer can personally vouch for the reliability of the method of securing bottled fruits by tying tightly a thick layer of cotton batting over the mouth in place of the ordinary screw-top. Through this fibrous cap the air can make its way with ease, but all solid particles, both living and dead, will be stopped. As bottles and cans of fruit are ordinarily sealed at the boiling temperature, there is a shrinkage of the contents as cooling proceeds, and a consequent tendency of the outer air to force an entrance. This outside pressure will depress the top of a well-sealed can; but if fermentative changes have taken place within, the accumulation of gas will cause a bulging of the top and bottom. Beware of such over-filled cans, their contents are spoiled.

Mineral Poisons in Canned Goods.—The use of canned foods is fraught with danger from the fact that poisonous compounds are often formed by the action of the juices upon the metal of the can; and such are sometimes derived from the solder and the soldering fluids. Tinned ware is often adulterated with lead; and cases of lead-poisoning are not infrequent among the users of canned goods. Zinc chloride (butter of zinc) is largely used as a soldering medium, and some

of this poisonous substance occasionally becomes mixed with the contents of the can.

Drying, an effectual method of preservation, admits of application to meats, vegetables, and fruits. Appearance indicates, and analysis proves, that foodstuffs in their natural condition all contain a large proportion of water. The bacteria of putrefaction cannot thrive unless freely supplied with water; dryness renders them inert, and is an effectual hindrance to their destructive growth. Succulent vegetables and fruits by drying lose many of their flavoring ingredients, though but little real nutriment is sacrificed. To be prepared for the table, dried foods should be soaked in water, that they may absorb the proportion of liquid formerly lost.

Chemical Antiseptics are also used. But for the very small quantities of antiseptic chemicals necessary to produce the desired effect, great danger would attend their use, for none of them are of themselves conducive to health.

Common Salt is one of the most efficient among these. If dry salt be added to fresh meat, a brine soon forms; this is due to the strong attraction which salt possesses for water, whereby it robs the meat of its juices; the meat in itself becomes in reality dryer, though outwardly it appears in the very opposite condition. That salted meat does not putrefy is due mainly to the abstraction of water; though salt itself in large quantities is fatal to bacterial existence. Much of the mineral matter of the meat is dissolved with the juices in the brine during the salting process; and

meat so preserved is consequently deficient in these essentials. The eating of salted flesh, if long continued, may produce serious derangement of health. Scurvy is a common disease among sailors who are fed on such meat.

Sugar is also a valuable antiseptic; it is used in pickling and curing meats, but more especially in the preserving of fruits. By dissolving in the fruit juices, and thus converting them into syrups, sugar exercises a drying effect upon the tissues, and so retards decomposition; and farther, the mere presence of sugar in abundance prevents the growth of bacteria. In dilute syrups, fermentation may be set up, unless the containing vessels are secured by hermetic sealing against the possible entrance of germ-laden air, as is done in the case of bottled and canned fruits.

Alcohol preserves organic tissues immersed in it, by uniting with the constituent water, and thus drying the solid parts. A little strong alcohol poured upon the white of an egg converts the albumen into a tough, leathery mass, which analysis shows to be very deficient in water as compared with the liquid white; and by the process the alcohol is correspondingly diluted. Alcohol exerts a destructive effect upon bacterial organisms that may find entrance to it, and thus it tends to prevent putrefactive changes.

Vinegar checks decomposition of organic matter. Its general properties and uses have been already dwelt upon. Fish and meats are sometimes preserved in *oil*. This medium prevents the access of air to the immersed substances, and thus effectually

guards against the entrance of germs of decomposition.

Creosote is a powerful antiseptic; a very weak solution of the substance, if poured upon meat, will prevent decomposition of the latter even in the hottest weather. Creosote is the chief of the irritating constituents of smoke, and the efficacy of smoke-drying as a means of preservation is mostly due to the influence of this substance. The amount of creosote necessary for preservation is extremely small, else great danger would attend its use, for the substance is a strong poison.

Various preparations of *boric acid* are now used as antiseptics; principally for preserving meats. The acid is introduced into the circulatory system of animals before death so that the flowing blood may distribute the material throughout the body.* The so-called "glacialine," now sold in packages and warranted to be a safe preservative, consists mainly of

*Mattieu Williams thus describes the process and illustrates its efficacy: "The animal is rendered insensible, either by a stunning blow, or by an anæsthetic, with the heart still beating. A vein, usually the jugular, is opened, and a small quantity of blood let out. Then a corresponding quantity of a solution of boric acid raised to blood heat is made to flow into the vein from a vessel raised to a suitable height above it. The action of the heart carries this through all the capillary vessels into every part of the body of the animal. * * * After the completion of this inoculation, the animal is bled to death in the usual manner. From three to four ounces of boric acid is sufficient for a sheep of average weight, and much of this comes away with the final bleeding. On April 2nd, 1884, I made a hearty meal on the roasted boiled and stewed flesh of a sheep that was killed on February 8th, the carcass being in the meantime in the basement of the Society of Arts. It was perfectly fresh, and without any perceptible flavor of the boric acid; very tender and full flavored as fresh meat."

borax. A small amount of borax added to milk hinders fermentation and thus prevents for a time the souring of the liquid.

Salicylic acid is growing in favor as a preservative of fruits and vegetables. The use of this has been proved by experience to be detrimental. The substance is a potent medicine, and when used continuously or in large quantity it is a poison. Many of the preservative powders and solutions now offered for sale consist mainly of salicylic acid, and should be avoided.

Preservation of Eggs.—Eggs may be preserved by varnishing the porous shells, so as to prevent the entrance of air. By coating the exterior with an impervious layer, the natural appearance of the inner parts may be preserved. This may be effected by dipping the eggs in a prepared solution of gum, or in melted fat or paraffine. They should then be carefully packed. Dr. Youmans kept eggs in good condition for upwards of a year, by packing them in salt, small ends downward; after that time they had lost nearly half their weight, but had not putrefied; the interior of the egg, however, had become thick and shrunken. Among recent methods, that of subjecting eggs to the action of sulphur dioxide, produced by the burning of sulphur, has produced good results.

REVIEW.

1. Show the great liability of food stuffs to undergo decay.
2. Define "putrefaction," and "fermentation."
3. What does the microscope teach us as to the nature of such decomposition processes?

4. Explain the effect of freezing in preventing decay.
5. Illustrate the practical use of this mode of preservation.
6. Explain the effect of hermetic sealing in preventing decay.
7. Explain why pure thoroughly filtered air will not induce decay in perishable articles.
8. What practical application may be made in preserving fruit?
9. Describe the process of canning fruits, vegetables and the like.
10. What dangers attend the use of canned goods?
11. Explain the effect of drying in preserving foods.
12. What is a chemical antiseptic?
13. Name the principal chemical antiseptics.
14. Explain the preserving effect of salt.
15. Of sugar.
16. Of alcohol.
17. Of oil.
18. Of creosote.
19. Of boric acid.
20. Of salicylic acid.

PART IV.

CLEANSING AGENTS; AND POISONS AND THEIR ANTIDOTES.

CHAPTER 36.

CLEANSING AGENTS.

Water as a Cleansing Agent.—The great solvent power possessed by water renders that liquid particularly useful as a cleansing medium, and the need of such a substance must be apparent to all. The furniture of the house, the utensils of the cook-room, the clothing of the body, and especially the skin itself, all call for periodical washings. Though water has appropriately been termed the "universal solvent," it possesses widely varying dissolving powers for different substances; thus, a pinch of sugar or of salt will dissolve readily in a goblet of water, whereas a like quantity of sand may remain apparently undissolved for an indefinite time, and for oily matters water exhibits positive repulsion. Yet very delicate chemical analysis shows that some portion even of sand and of oil may be dissolved by water. As a rule, the solvent power of water is favored by heat; the use of hot water for laundry and house cleansing is therefore indicated.

Alkalies as Cleansing Agents.—A greatly increased solvent effect is produced by adding to the water certain chemical substances, prominent among which are the alkalies, potash, soda, and ammonia. From very early times, people have been in the habit of using wood ashes as an aid in washing clothes; the effective ingredient of the ashes being potassium carbonate

(commonly called "potash," because prepared from the ashes of fires used in heating the cooking pots). A strong solution of potash, or of either of the other alkalies named, possesses strongly corrosive powers; only very dilute solutions can therefore be used for ordinary cleansing purposes, lest while removing the impurities the fabrics and objects themselves be injured.

Soaps.—Experience has taught that it is better to restrain the corroding ardor of the alkalies by first combining them with fats so as to form soaps. Ordinary fats and fixed oils consist each of two main ingredients, viz., glycerine and an acid, the latter commonly called a fatty acid. When heated with strong alkalies, fats readily decompose, liberating their glycerine, while the fatty acids unite with the alkalies to form salts. Thus, fats containing olein, if heated with soda, would form glycerine and sodium oleate; palmitin and stearin, the other two common fats, if similarly treated, would form sodium palmitate and sodium stearate; if potash were used as the alkali, potassium oleate, palmitate, or stearate would be formed. These compounds of alkalies and fatty acids are soaps. Most soaps dissolve in water, producing very viscid solutions, which when agitated readily entangle air, producing lathers. When used with hard waters, the alkali in the soap is exchanged for the lime or magnesia of the water, and thus soaps of lime or magnesia are formed; these are insoluble in water, and rise to the surface as scum.

Soap-making.—The chemical process of forming

soap by decomposing fats through the agency of alkalies, is known as *saponification*; it may be watched and studied at any soap-boiling establishment. The alkalies used in soap making are usually the hydrates of the metals; these, from their great corrosive powers, are called *caustic alkalies*. The soap in forming dissolves in the water present; as the boiling continues much of the water is evaporated, the soap then separates from solution and rises to the surface; this is removed, shaped in molds, and allowed to partially dry before it is used. If caustic soda be used as the saponifying alkali, the soap may be more advantageously separated by adding common salt to the soap solution, whereby a strong brine is formed, which coagulates the soap and causes its ready separation from the water. This "salting out" is not practicable in the making of potash soaps, because the salt would decompose the potassium compound, forming a soda soap.

Soaps—Hard and Soft.—There is great difference between the soaps made from these two common alkalies. Caustic potash is highly deliquescent; that is to say, it possesses a great thirst for water, and so keeps the soaps formed by it in a partially liquid state; from such soaps the glycerine cannot be well separated, this adds to the softness of the soap. Potash soaps are always *soft soaps*; soda on the other hand forms *hard soaps*. The consistency of the soap depends in some degree upon the fats used, though this condition is mostly influenced by the alkali; thus, hard tallow will produce a firmer soap than will olive oil;

yet an oil with soda will saponify to a comparatively hard soap, while solid tallow with potash will produce a semi-liquid soap.

Fats Used in Soap Making.—Among the common fatty bodies used in the preparation of soap may be named tallow, lard, palm oil, olive oil, cotton-seed oil, cocoa-nut oil, for hard soaps; and fish oil, linseed oil, and marrow for soft soaps. Certain fine grade toilet soaps are made of almond oil and spermaceti. Cocoa-nut oil is peculiar among fats, it being unaffected by weak alkalies, but readily saponifiable by strong alkalies; the resulting soap is soluble in brine, and, consequently, cannot be separated from water in the course of manufacture by "salting out." The oil is heated to a low temperature only, the lye is then stirred in, and saponification takes place at once. Cocoa-nut oil soap lathers with salt water; it is therefore valuable for use at sea, and is known as *marine soap*.

Colored Soaps.—Common yellow soaps contain resin; other tints are usually produced by special coloring matters. The mottled appearance of some soaps is due to the presence of insoluble metallic oxides, which are stirred into the soap as it hardens. Transparent soaps are produced by dissolving good hard soap in alcohol, then evaporating the solution till a clear jelly is obtained; such soaps are usually pure and good, though they waste rapidly and are costly. True *Castile soap* is made from olive oil and soda; the color is due to metallic oxides stirred into the mass. Many imitations of Castile soap are

now made from common fats. Glycerine soaps consist of a mixture of hard soap and glycerine; the latter substance in small quantity only; an excess of glycerine causes the soap to soften and gives but weak lathering properties, whereas a small amount of glycerine renders the lather tenacious and persistent.

Impure Soaps.—The poorer grades of soaps are sometimes made from very impure fats; in such the microscope has revealed the presence of bits of bone, half-decayed areolar tissue, and even pus cells; very serious results may follow the use of soaps of this sort, from the poisonous matter being absorbed through the skin. Such foul accompaniments, however, are comparatively rare; the chief inconvenience attending the use of poorly made soaps lies in the excess of free alkali which they contain. The smarting sensation following the use of such soaps on the skin is caused by the solvent action of the free alkali; relief may be found through the application of some verp dilute acid, such as vinegar, or lemon juice.

Adulterated Soaps.—Many soaps are largely adulterated, though most of the additions are comparatively harmless. The commonest adulterants are fuller's earth, starch, and soluble silicates. Sodium silicate enables soap with which it is mixed to absorb a large quantity of water, and so greatly increases the weight; though, as the substance itself is a harmless detergent, the ill effects of its introduction are somewhat modified.

Washing Compounds.—With some soaps a quantity of fine sand or other hard insoluble powder

is incorporated; this by its abraiding action aids the cleansing operations. Most washing compounds are partially dried and finely divided soaps; all such substances, as also common "washing powder," contain a great excess of alkali. "Washing fluids" are mere solutions of the caustic alkalies, soda and potash; such are of advantage where very hard waters are used, though such excess of alkali is generally injurious to the skin, as also to most fabrics submitted to its action. When soap dissolves in water, some of its alkali is set free; this combines in the washing process with the oily matters of the dirt, and by saponifying such renders them miscible in water.

Ammonia.—Besides soap, and the free alkalies, potash and soda, which are the commonest cleansing agents, *aqua ammonia* is also largely employed. This should be used only when greatly diluted with water. With oily matter it forms a soapy fluid, which is soluble in water; hence the value of ammonia for removing grease from cloth, etc. Water containing a tablespoonful of ammonia to the gallon is an excellent wash for woodwork, and such a mixture is frequently applied to carpets for the purpose of brightening their colors.

Other Solvents for Fats.—Besides ammonia, already mentioned, spirits of turpentine, camphene (rectified turpentine), and benzine (gasoline), are also efficient solvents for most fixed oils; they are therefore useful in removing grease from clothing.

REVIEW.

1. Show the value of water as a cleansing agent.
2. By what means may the solvent powers of water be increased.
3. What is soap ?
4. Describe the general method of making soap.
5. Explain the cleansing action of soap.
6. What is the scum formed by soap when acted upon by hard water ?
7. Explain the process of saponification.
8. Explain the difference between hard and soft soaps.
9. Name the principal fats used in making soaps.
10. What do you know of Castile soap ?
11. Of glycerine soaps ?
12. Show the dangers of using soap made of impure fats.
13. What do you know of the composition and action of washing powders ?
14. Explain the cleansing action of ammonia.
15. Name the common cleansing agents with which you are acquainted.

CHAPTER 37.

BLEACHING.

Sun-Bleaching.—It is often found desirable to modify or to remove the natural colors of textile goods; the process of whitening such fabrics is known as bleaching.* It has long been an art among men, they having learned its fundamental principles from observing certain operations in Nature. Light and air are universal bleaching agents.

The earliest processes of artificial bleaching consisted in exposing the colored fabrics to light and air. This was accomplished by spreading the goods on grass plats in the open sunshine, and by occasionally wetting them if dews or rain did not afford sufficient moisture. The explanation of the whitening process so conducted is simple as far as we understand it; the oxygen of the air unites with the organic compounds constituting the coloring matters, thus changing their composition with consequent loss of their property of color. This operation is most applicable to cottons and linens. Under the best conditions sun-bleaching is a slow process; in Holland where the art was most highly developed, the bleaching required for its completion eight or nine months; and oftentimes if the

* The old English name for bleachers is "whitesters," or "whitsters;" it fully expresses the nature of their occupation.

season were cold and wet the fabrics were injured by the continual exposure. The Dutch mode of procedure in bleaching, consisted of treating the cloth for a week with caustic alkali or lye; then came an immersion in buttermilk, and then the many months' exposure to sunlight and dew. The large space needed for the process gave to bleaching establishments the common name of "bleach-fields."

Chemists have discovered several substances that possess strong bleaching powers. Of these, chlorine and sulphur dioxide are among the chief; and they are the ones that are best adapted for domestic application.

Chlorine as a Bleaching Agent.—Chlorine is a gas, yellowish green in color, and of penetrating, strongly suffocating odor. It is possessed of remarkably strong chemical affinity for other elements, and will often decompose other compounds to form with the elements combinations of its own. Upon this property depends the value of chlorine as a bleaching agent, and, as will subsequently be seen, its efficacy as a disinfectant also. The tinted petal of a flower, a green leaf, or a piece of cloth dyed with vegetable colors, may be readily whitened by exposure to the gas. To demonstrate, place in a wide-mouth bottle a little chloride of lime;—this substance is a convenient source of chlorine, and is commonly known as "bleaching powder;" pour upon it a little dilute acid,—muriatic acid is best;—then quickly cover the mouth of the jar with a plate of glass. The vessel will soon become filled with the green gas,—chlorine;

if you desire to test its odor, do so cautiously, for if inhaled in quantity it produces painful and injurious spasms. Suspend in the upper part of the vessel some bits of colored calico, and a colored flower,—all of which must be moistened; the colors disappear with magical quickness.

Another pretty demonstration of the decolorizing action of chlorine consists in conducting the gas or pouring chlorine water into red ink, colored wine, infusion of red cabbage, or of indigo; the tints almost instantly disappear. Printers' black ink is not so affected; as its color is due to finely divided carbon (lampblack), which is not eager to form combinations with other elements. Dry substances are not whitened by chlorine, and this fact is a key to an understanding of the bleaching process. Chlorine possesses a strong affinity for hydrogen, so strong indeed as to readily take the hydrogen from water, thus leaving the oxygen free; this oxygen in its nascent or freshly liberated state eagerly unites with the organic coloring compounds, and, as was explained in the case of sun-bleaching, robs them of color. So that chlorine is not the true bleacher after all. Oxygen is the efficient color destroyer, the chlorine simply liberates the oxygen from its combination in water. Thus there is great similarity between the processes of sun-bleaching and "chlorine-bleaching:" each is a result of oxidation.

The bleaching operation may be carried too far; for if after the coloring matters have been acted upon chlorine be still allowed to decompose the water con-

tained within the pores of the cloth, the energetic oxygen will attack the textile fibers themselves, and this will rot the fabrics. Exposure to gaseous chlorine is very apt to partially destroy the fabrics; a more practical method, and the one most commonly adopted, consists in immersing the goods to be bleached in a solution of chloride of lime; they should be kept in the bath several hours,—sometimes days are required; they are then to be removed, and if the whitening be not satisfactory they should be placed in a tub of acidified water; the acid will liberate chlorine in quantity from the bleaching powder within the pores; the acid treatment must be carefully watched, lest it result injuriously to the goods.*

Sulphur Dioxide in Bleaching.—Colors bleached through the agency of chlorine cannot be restored, the pigment having been destroyed. Chlorine-bleaching is not applicable to straw, wool or silk. For these, *sulphur dioxide* is employed as a whitener. This gas may be produced by burning sulphur in air; it is colorless, and produces an intensely irritating effect within the

* "A very elegant application of chlorine to bleaching purposes is made in the printing of bandanna handkerchiefs. The white spots which constitute their peculiarity are thus produced. First of all, the whole fabric is dyed of one uniform tint, and dried. Afterwards, many layers of these handkerchiefs are pressed together between lead plates, perforated with holes conformable to the pattern which is desired to appear. Chlorine solution is now poured upon the upper plate, and finds access to the interior through the perforations. By reason of the great pressure upon the mass, the solution cannot, however, extend laterally further than the limits of the apertures, whence it follows that the bleaching agent is localized to the desired extent, and figures corresponding in shape and size to the perforations are bleached white upon the dark ground." FARADAY.

respiratory passages. Like chlorine, it is soluble in water, and its solution possesses the essential properties of the gas. Its bleaching powers may be prettily illustrated by holding a moist red rose over a bit of burning sulphur; a lighted match held beneath the flower is often effective. The process of sulphur-bleaching is conducted by moistening the articles and suspending them in closed chambers in which sulphur is being burned. A large box or an inverted tub may be used as a bleaching chamber. The moistening of the goods is to aid the absorption of the gas. The coloring matters so bleached are not in reality destroyed; the union between them and sulphur dioxide is an unstable one, and the colors are after a time restored in part. Flannels that have been bleached with sulphur dioxide often regain their color when washed with alkaline soaps. Certain chemicals—e. g. sulphuric acid, will promptly restore the color to articles so bleached. To illustrate this, prepare an infusion of logwood; conduct into it gaseous sulphur dioxide, or pour into it an aqueous solution of the gas; the color immediately disappears; now add a little sulphuric acid; the color is as promptly restored. Sulphur-bleaching is therefore only practiced in cases to which chlorine is not applicable, as in whitening silk, wool, and straw.

REVIEW.

1. What is bleaching?
2. Describe the earliest known processes of bleaching.
3. Name the commonest chemical bleaching agents.

4. Describe a demonstration of the bleaching action of chlorine.

5. How may chlorine be prepared for experimental work?

6. Explain the chemical changes occurring in chlorine bleaching.

7. Name a common and an easily employed source of chlorine.

8. Describe the method of using chloride of lime in bleaching.

9. Explain the methods of printing bandanna handkerchiefs.

10. For what materials is chlorine not adapted as a bleaching agent?

11. Describe a method of preparing sulphur dioxide.

12. State some of the properties of sulphur dioxide.

13. Explain the instability of the whitening resulting from sulphur dioxide bleaching.

CHAPTER 38.

DISINFECTANTS.

Disinfectants and Deodorizers.—Certain kinds of impurity cannot be removed from our dwellings by the ordinary methods of cleansing. The presence of dust in the house has been shown to be universal; the complex nature of the dust, consisting as it does of inorganic and organic matters, and even of living organisms, has been dwelt upon; the close relationship between the progress of contagious diseases within the body and putrefaction without is now well understood. Following a consideration of these facts, the operation of disinfectants will be clear.

A disinfectant is a substance that destroys the effluvia of putrefaction, and the poison of contagion; yet the term, by a popular inaccuracy, is applied also to absorbents and deodorizers. Foul smells are usually associated with poisonous properties; the disagreeable odor seems to be a danger signal, affixed in wisdom to many noxious matters. Fatalities from inhalation of the toxic coal gas, the nauseating hydrogen sulphide, and the deadly prussic acid would be more frequent but for their disgusting odors. Substances that absorb ill-smelling matters, therefore, may be of value, yet they hold the offensive gases much as a sponge retains water, and they may again allow the escape of the foul matter.

Certain odorous substances are wrongly termed deodorizers, such as cascarilla, cologne, and other extracted perfumes, musk, fragrant spices, aromatic mixtures, burning coffee, and even smoldering paper and rags; these, however, merely hide the bad odor by substituting a stronger one. Such substances are almost valueless as disinfectants.*

Charcoal and Lime are efficient absorbents of many foul gases. A solution of hydrogen sulphide shaken with fresh charcoal loses almost immediately its foul odor. Lime is less efficacious, yet it is valuable. The practice of whitewashing the walls of rooms, and especially of cellars and such places is very beneficial in sweetening the inclosed atmosphere; though, as the lime soon loses this power, frequent renewal of the wall-wash is necessary.

The merits of charcoal as an absorbent of gases are not generally recognized. It is used in water filters to arrest gaseous impurities; organic filth of many kinds, even the bodies of dead animals, if covered with a layer of freshly heated charcoal may undergo decomposition with no escape of foul effluvia; tainted meat packed in charcoal loses its disagreeable smell; and the air of sick rooms may be greatly improved by placing

* "They (perfumes) are the only resources in rude and dirty times, against the offensive emanations from decaying animal and vegetable substances, from undrained and untidy dwellings, from unclean clothes, from ill-washed skins, and ill-used stomachs. The scented handkerchief in these cases takes the place of the sponge and the shower bath; the pastile hides the want of ventilation, the attar of roses seems to render the scavenger unnecessary, and a sprinkling of musk sets all other stenches and smells at defiance." (Quoted.)

therein charcoal in shallow pans. Finely divided charcoal is one of the most efficient and least harmful of powders for the teeth; being soft it produces no injurious abrasions of the enamel, while its deodorizing action does much to sweeten the mouth.* A small amount of pure charcoal swallowed immediately after onions will keep the breath free from disagreeable effluvia. A lump of clean charcoal in a cooking vessel with cabbage, onions, or other strong-smelling vegetables, will prevent the escape of disagreeable odors. Roasted coffee is partially charred vegetable matter; a few coffee seeds may be substituted for the lump of charcoal in the cooking process just named. Bone black or animal charcoal has great affinity for the elements of vegetable colors, and is of great use as a decolorizer of syrups, etc., which are filtered through it.

Chlorine as a Disinfectant.—Chlorine, in its pure state is a pale yellowish-green gas; intensely irritating if inhaled. Its chief properties have been considered in connection with its use as a bleaching agent (page 359). Hydrogen sulphide, ammonia, and most other compounds formed by the putrefaction of organic matter are decomposed by the gas. If allowed to escape in closed rooms it will destroy or render inert most foul matters; but it is likely to bleach the

* Charcoal from wood is apt to be "gritty," such may be of injury if rubbed on the teeth. The best kind for the purpose named may be made by charring the crust of bread. Let the bottom crust of a loaf be removed in one piece, and this be completely charred before or over a glowing fire. It is then to be finely pulverized.

colors of furniture and drapery in the presence of moisture, and to corrode metals. Its most accessible source is *chloride of lime*, or *bleaching powder*, which is prepared by saturating slaked lime with the gas. The powder contains about 30 per cent. available chlorine, which is set free very slowly by mere exposure; but may be liberated very rapidly by the addition of an acid. The common attempt at disinfection by simply scattering lime chloride about the premises is a very ineffectual one; the substance should be mixed with acid—hydrochloric acid, sulphuric acid, or even strong vinegar may be used. For disinfecting rooms, chlorine may be liberated by mixing 4 ounces of hydrochloric (muriatic) acid, previously diluted with three times its volume of water, and 1 pound of chloride of lime. Let the mixture be made in an earthen vessel; the room should be immediately closed, and be kept unopened for 24 hours. Another method of chlorine preparation consists in treating manganese dioxide (two parts by weight) with strong hydrochloric acid (three parts by weight).

Sulphur Dioxide as Disinfectant.—Sulphur dioxide is a colorless gas, entirely irrespirable. It may be easily prepared by burning sulphur, and is an efficient disinfectant. It is in most respects best adapted among disinfectants for general use. Wet fabrics containing vegetable dyes are bleached, however. To prepare and use the gas:* set an iron pan

*The "sulphur candles" now offered for sale by druggists afford a convenient method of disinfecting by sulphur on a small scale; but being somewhat more expensive the method is not likely to displace the simple sulphur burning for large buildings. The

on bricks in the middle of the floor; as an additional precaution the bricks may be placed in a shallow tub containing water; put the sulphur (roll brimstone is best adapted) in the pans, allowing at least two pounds for a room 10 feet square; light by adding a small shovelful of glowing coals, or by pouring a tablespoonful of alcohol over the brimstone and applying a match. Let the room be closed, and remain so for 24 hours. Do not use chlorine and sulphur dioxide together; they partially neutralize each other.

Carbolic Acid is prepared from coal tar; it is a colorless crystalline solid, though by exposure to light and air it soon darkens, and if at all diluted it becomes liquid. In an unmixed state it is very corrosive to organic substances, but being soluble in water it may be diluted to any degree. It is a sure destroyer of bacterial life if brought in contact with the organisms, and is also an antiseptic, acting in this respect much like creosote. A two per cent. solution of carbolic acid; i. e. 2 parts acid diluted with 98 parts water, is suitable for most purposes of disinfection. The odor of the acid is objectionable to many persons; this may be somewhat modified by dissolving camphor in the acid before dilution. Many prepared disinfectants now offered for sale are mixtures of carbolic acid and

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sulphur candle consists of a quantity of sulphur which has been poured while molten into a shallow dish of sheet iron. The sulphur mass is penetrated by porous wicks, previously prepared by soaking in a solution of nitre, so that they burn readily much as fuses do. After preparing the room, all that is necessary in using such a candle is to set it in a wash-bowl or other convenient vessel containing a little water, and light the wicks.

dilutents. Carbolic powders consist of the acid mixed with sawdust, lime, or clay.

Thymol is another product of coal tar distillation. Its odor is agreeable, and as its disinfecting action is similar to that of carbolic acid, it is largely used as a substitute for the latter. It may be purchased in the solid state, or as spirits of thymol, consisting of 1 part thymol dissolved in 3 parts alcohol of 85 per cent. strength. To prepare for use, add one table-spoonful spirits of thymol to a half gallon of water. This solution may be sprinkled about the apartment, even on carpets and draperies without serious detriment; still further diluted, it may also be applied to the flesh as a wash, after exposure to contagion. Do not allow it to enter the eyes.

Ferrous Sulphate, or Green Vitriol, also called copperas, may be used as a disinfectant; it is cheap. It exists as pale green crystals, and is very poisonous. Ferrous sulphate is a good disinfectant; for use it should be dissolved in water,—2 pounds of the crystals to a gallon of water. This solution may be improved by the addition of 2 ounces carbolic acid per gallon of fluid. When required in large quantity, a basket containing fifty or sixty pounds of the crystals may be suspended in a barrel of water; the solution soon becomes saturated.

Lime and Charcoal, though absorbents rather than disinfectants, occur as ingredients of many patented disinfectant preparations. Gypsum (lime sulphate) is mixed with carbolic acid, and used for disinfecting stables, etc.

Corrosive Sublimate, called also mercuric chloride, is a powerful disinfectant, and acts by destroying the germs of decay. It readily coagulates albuminous matters. One part of the substance in 1000 parts of water forms a solution of sufficient strength to kill most bacteria. It is a deadly poison, and does not admit of general use. It should be employed only under skilled direction.

Zinc Salts as Disinfectants.—Certain salts of zinc, especially the sulphate (white vitriol), and the chloride (butter of zinc), are good disinfectants. With albuminous matters they form insoluble compounds, and act as absorbents for certain gases. The substances are poisonous and must be used with care. A very good zinc disinfectant consists of zinc sulphate, 1 pound; common salt, ½ pound; and water, 4 gallons. Infected clothing, bedding, and the like may be immersed and boiled in the solution.

Lead Chloride is of service as a disinfectant, but must be used with care because of its poisonous nature. To prepare: Dissolve 1 drachm of lead nitrate in a quart of boiling water; dissolve also 4 drachms of common salt in a bucket of water, and mix the solutions. A copious precipitate of lead chloride will form, much of which will settle; the supernatant fluid is ready for use. It may be sprinkled about the floor, or in drains and gutters.

Heat, Air, and Light as Disinfectants.—Heat is an important agent of disinfection. Clothing, carpets, and such articles as admit of this treatment, should be boiled in water, or subjected to a dry heat

in an oven at 250° to 300° F., for several hours. Woolen fabrics are injured by this treatment.

Air and Light.—For house disinfection, abundance of fresh air, free access of light, and strict cleanliness are among the most valuable of disinfectants. No chemical preparation can take the place of the natural purifiers, air and light, and no cure of uncleanliness is equal to the prevention of such a state.

Below is given a brief code of instructions for the **Management of Contagious Diseases,** as authorized by the National Board of Health:*

INSTRUCTIONS FOR DISINFECTION.

Disinfection is the destruction of the poisons of infectious and contagious diseases.

Deodorizers, or substances which destroy smells, are not necessarily disinfectants, and disinfectants do not necessarily have an odor.

Disinfection cannot compensate for want of cleanliness nor of ventilation.

I. *Disinfectants to be employed.*

1. Roll sulphur (brimstone) for fumigation.

2. Sulphate of iron (copperas) dissolved in water, in the proportion of one and a half pounds to the gallon, for soil, sewers, etc.

3. Sulphate of zinc and common salt dissolved together in water, in the proportion of four ounces

* These instructions were prepared by a special committee of eminent scientific men. They are here quoted from Dr. Tracy's admirable little "Hand Book of Sanitary Information."

sulphate and two ounces salt to the gallon, for clothing, bed linen, etc.

II.—*How to use disinfectants.*

1. *In the sick room:* The most available agents are fresh air and cleanliness. The clothing, towels, bed-linen, etc., should, on removal from the patient, and before they are taken from the room, be placed in a pail or tub of the zinc solution, boiling if possible. All discharges should either be received in vessels containing copperas solution, or when this is impracticable, should be immediately covered with copperas solution. All vessels used about the patient should be cleansed with the same solution. Unnecessary furniture, especially that which is stuffed, carpets and hangings, should when possible be removed from the room at the onset, otherwise they should remain for subsequent fumigation and treatment.

2. *Fumigation* with sulphur is the only practicable method for disinfecting the house. For this purpose the rooms to be disinfected must be vacated. Heavy clothing, blankets, bedding, and other articles which cannot be treated with zinc solution, should be opened and exposed during fumigation as directed below.

3. *Premises:* Cellars, yards, stables, gutters, privies, cess-pools, water-closets, drains, sewers, etc., should be frequently and liberally treated with copperas solution.

4. *Body and bed-clothing*, etc. It is *best* to *burn* all articles which have been in contact with persons sick with contagious or infectious diseases. Articles

too valuable to be destroyed should be treated as follows: (a) Cotton, linen, flannels, blankets, etc., should be treated with boiling-hot zinc solution, introduced piece by piece: secure thorough wetting, and boil for at least half an hour. (b) Heavy woolen clothing, silks, furs, stuffed bed-covers, beds, and other articles which cannot be treated with the zinc solution, should be hung in the room during fumigation, their surfaces thoroughly exposed, and pockets turned inside out. Afterward they should be hung in the open air, beaten and shaken. Pillows, beds, stuffed mattresses, upholstered furniture, etc., should be cut open, the contents spread out and thoroughly fumigated. Carpets are best fumigated on the floor, but should afterwards be removed to the open air and thoroughly beaten.

Corpses, especially of persons that have died of any infectious or malignant disease, should be thoroughly washed with a zinc solution of double strength; should then be wrapped in a sheet wet with the zinc solution, and buried at once.

REVIEW.

1. What is a disinfectant?
2. Show the difference between true disinfectants and absorbents.
3. Between true disinfectants and deodorizers.
4. Show the value of charcoal as an absorbent.
5. What do you know of lime as an absorbent?
6. Explain the disinfecting action of chlorine.
7. How would you use chloride of lime as a disinfectant?
8. What do you know of sulphur-dioxide as a disinfectant?

9. How would you prepare and use sulphur dioxide in disinfecting?

10. What do you know of carbolic acid as a disinfectant?

11. How would you use it?

12. State what you know of the disinfecting value of thymol.

13. How would you use the substance?

14. For what special uses in disinfecting is iron sulphate adapted?

15. How should the substance be used?

16. What do you know of corrosive sublimate as a disinfectant?

17. Explain the use of zinc salts as disinfectants.

18. State the uses of lead chloride as a disinfectant.

19. Show the disinfecting value of heat.

20. Of fresh air and light.

21. Name the common disinfectants recommended by the National Board of Health for general use.

22. Give the principal instructions of this Board on "How to use disinfectants."

CHAPTER 39.

POISONS AND THEIR ANTIDOTES.

A Poison may be defined as any substance capable of producing within the animal or human body a noxious or deadly effect. This definition includes, of course, injurious chemical compounds of an inorganic nature, also certain vegetable products, and the venom of animals. Many poisonous matters produce local effects of irritation and pain, such as the strong acids and alkalies and corrosive mineral compounds; others act remotely upon the body, that is, through absorption by the blood and consequent derangements of the nervous system; such are called narcotic or neurotic poisons, and include opium, aconite, alcohol, etc. All poisons in large quantities operate speedily when taken into the body; though some are cumulative in their nature, that is, they may be taken in repeated doses each too small to produce alone serious effects, but by accumulating within the body they give rise to chronic derangements of increasing severity: of such poisons lead and arsenic are examples.

General Treatment in Poisoning Cases:—In most severe cases of poisoning, the symptoms will be clearly marked, and the attendant circumstances will likely indicate the nature of the poisonous substance used. Prompt measures for relief should be taken. As a rule, when it is found that a poison has been swallowed, the first thing to be done is to remove the

contents of the stomach, thus preventing farther absorption of the poison. If vomiting has not occurred, simple emetics should be administered. Among common emetics, the wine of ipecacuanha is good; give at least a tablespoonful in the case of an adult, less for children. In the absence of this, mix powdered mustard and salt in water—a teaspoonful of mustard and an equal amount of salt, the latter dissolved and the former well mixed in a pint of warm water. A tablespoonful of powdered alum, with an equal quantity of molasses, honey, or sugar, well stirred in water, is a good emetic dose. Mechanical irritation in the throat, as by tickling with a feather or the finger, will often induce vomiting. As quickness of action is of great import, repeat the emetic doses at frequent intervals (every ten or fifteen minutes) till copious vomiting occurs; then aid the operation by plentiful draughts of dilutent liquids, such as warm water, alone or with sugar; mucilage of gum-arabic (do not use the prepared gum mucilage, it contains poisonous ingredients), watery infusions of slippery elm, or flax-seed tea. A stomach pump, if at hand, may be used to good effect in cleansing the stomach.

Antidotes.—Another important step is to neutralize and thus render inert, as far as possible, the poison within the body; for this purpose certain antidotes should be given. The object of the antidote is to produce insoluble compounds which will be secure against absorption till they can be removed from the body. Below are named some of the commonest poisons and the antidotes well suited to each case.

Common Poisons and their Antidotes.

Strong Mineral Acids, such as nitric acid (aqua-fortis), hydrochloric acid (muriatic), sulphuric acid (oil of vitriol). Administer alkalies, such as soda, lime, whiting, magnesia, stirred in water. In the absence of these, take some plaster from the wall, crush fine, stir in milk, and administer; soap dissolved in water is good. In any case, follow with dilutents.

Organic Acids:—Oxalic acid is frequently taken by mistake, because of its resemblance to another household chemical—Epsom salts. Antidotes for oxalic acid—magnesia, chalk, or even wall plaster mixed with water. Prussic acid may be taken as oil of bitter almonds, or potassium cyanide; the effect is usually too rapid to admit of effectual antidotes, when possible, however, give *very dilute* ammonia, or chlorine water, or let the dilute gases from such be inhaled. Cold water applied to the spine is beneficial.

Strong Alkalies, such as ammonia, potash—as caustic potash, potash lye, pearlash, potassium nitrate (saltpeter); soda, as soda lye, etc. Give freely dilute acids, such as vinegar, citric acid, or tartaric acid, in water; these tend to neutralize the alkali. Give also large doses of oil, as olive oil, linseed oil, or castor oil; the oils form soap with strong alkalies, and so delay their ill effects.

Antimony compounds, as tartar emetic, wine of antimony, etc. Vomiting is of great importance. Give astringent infusions, as strong green tea; let tea

leaves be chewed and swallowed; infusion of oak-bark, nut galls, or tannin.

Arsenic:—Usually taken as white arsenic, Paris green, Scheele's green, cobalt powders; and among patented preparations: Fowler's solution, and various mouse and rat poisons. Give abundance of milk and white of eggs. The best antidote is the hydrated peroxide of iron; to prepare which: pour together solutions of perchloride of iron and dilute ammonia, both of which may be obtained at drug stores; a brown precipitate forms in the mixture; strain through linen; mix the brown mass with water and administer freely.

Copper Salts: as copper acetate (verdigris) often imbibed from unclean copper vessels used in cooking or pickling; copper sulphate (blue vitriol). Give freely of milk, white of eggs, and carbonate of soda.

Iron: as iron sulphate (green vitriol). Give carbonate of soda and plenty of mucilaginous drinks.

Lead: as lead acetate (sugar of lead), lead carbonate (white lead), red lead, also from water that has been kept in leaden pipes or vessels. Give *very dilute* sulphuric acid, or Epsom salts, in water. Administer oil and mucilaginous drinks with emetics. In chronic cases of lead poisoning, as in "leading" from exposure to fumes of the metal, repeated doses of *highly diluted* sulphuric acid, or of potassium iodide, may be recommended.

Mercury: as mercuric chloride (corrosive sublimate), ammoniated mercury (white precipitate), mercuric oxide (red precipitate), mercuric sulphide (ver-

milion.) Give white of egg in abundance, or flour mixed with water or milk, or soap and water. *Avoid strong emetics* or irritating substances. Use the stomach pump if possible.

Silver: as silver nitrate (lunar caustic). Give salt and water, then oil.

Zinc: as zinc chloride (butter of zinc), zinc sulphate (white vitriol). Zinc salts are themselves emetics; relieve the vomiting by dilutent drinks, and give sodium carbonate in water.

Phosphorus, from matches and vermin poisons. Give magnesia, or chalk, in water; flour in water; follow with mucilaginous liquids in abundance.

Certain *Gases* are sometimes breathed with toxic effect. For chlorine inhalation, let the sufferer cautiously breathe ammonia. In cases of poisoning from carbon dioxide, carbon monoxide (from fumes of coke or of burning charcoal), hydrogen sulphide, illuminating gas; relieve the stupor by applying cold water to the head,—give stimulants, and establish artificial respiration. To effect this, take the patient into the fresh air, and, except in the severest weather, expose the face, neck, and chest; clear the throat of mucus by turning the patient face downward with mouth open; hold dilute ammonia to the nostrils. If respiration does not take place, put the patient face downward, then roll the body almost over and back again, regularly (about fifteen times a minute); this causes alternate compression and expansion of the chest and favors the influx and escape of air. Rub the limbs upward, using considerable energy.

Narcotic poisons:—as opium (gum opium, laudanum, paregoric, infusion of poppies, soothing syrup; cholera mixtures; most patented "cordials"), digitalis, aconite, hemlock, belladonna; stramonium. Give emetics, or use stomach pump promptly. Keep the patient awake, in motion if possible; dash cold water on head and shoulders, administer strong coffee or tea; also vinegar or lemon juice. Keep the limbs warm; if necessary resort to artificial respiration. As consciousness returns, continue the use of coffee and give weak stimulants, such as wine or brandy in water.

Strychnine and *brucine* (nux vomica) are somewhat allied to the foregoing, though these usually produce violent spasms. Cautiously administer chloroform or ether to quiet the spasms; then give powdered charcoal in water (Walker).

Irritant vegetable poisons, such as croton oil, and many essential oils and essences, are often swallowed with poisonous effect. Vomiting is likely to occur spontaneously; if not, however, administer emetics without delay, aid vomiting by warm draughts, and follow with an efficient purgative. Give vinegar, lemon juice, or strong coffee.

Poisonous meats, *fish*, or *cheese* are sometimes eaten. Evacuate the stomach without delay by emetics and purgatives, and give good doses of vinegar and water. Hutchinson recommends that this treatment be followed by small doses of ether with a few drops of laudanum in sweetened water.

Animal venom may be received from bites of mad dogs, and of snakes, and spiders, and the stings of

insects. Wash the wound with dilute ammonia; if on a limb, tie a bandage above the place of injury; if possible let the wound be freely sucked, the mouth being afterward well rinsed with water. Moderate amounts of alcoholic stimulants may be given. In severe cases ammonia may be injected into the veins,—only a competent physician or surgeon should attempt this operation. As an extreme measure, the wound may be cauterized by the application of nitrate of silver, or by pressing the heated point of a small poker, or a knitting needle, into the wound. In the case of *insect stings*, extract the sting if still in the wound: a pair of forceps will aid in this, or the barrel of a small key may be pressed around the sting. Apply to the wound a little dilute ammonia, or spirits of camphor, or moistened soda; or in lack of these, alkaline mud, or earth mixed into a mud with saliva. A cloth dipped in a weak aqueous solution of carbolic acid may be applied to the affected part. If symptoms of internal distress make their appearance, give *cautiously* four or five drops of carbolic acid in a wine glass of water.

These are but a few of the commonest poisons; the antidotes recommended are such as are likely to be of ready access.

REVIEW.

1. What is poison?
2. What methods of general treatment would you follow in cases of poisoning?
3. What is a chemical antidote for a poison.

4. Name the antidotes and general treatment you would employ in cases of poisoning from the following substances; as far as possible explaining the action of the antidote in each case:

5. Sulphuric acid.
6. Oxalic acid.
7. Prussic acid.
8. Ammonia.
9. Potash.
10. Soda.
11. Tartar emetic.
12. Arsenical compounds.
13. Copper salts.
14. Iron salts.
15. Lead compounds.
16. Mercury compounds.
17. Silver nitrate.
18. Zinc compounds.
19. Phosphorus.
20. How would you treat a case of poisoning from coal gas?
21. Name the chief narcotic poisons.
22. How would you treat a case of opium poisoning?
23. Of strychnine poisoning?
24. How would you treat a case of snake-bite?
25. Of stinging by insects?

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